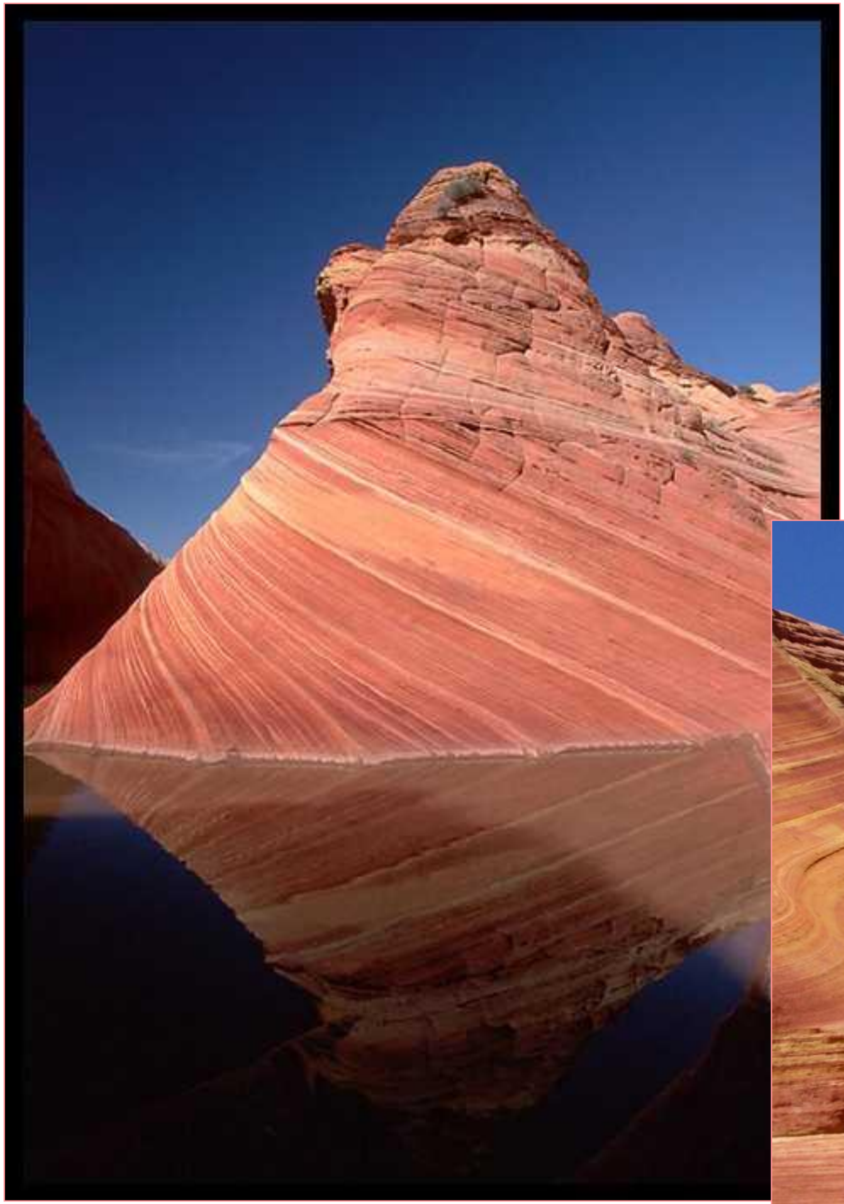
Evaluation of Laminated Reservoirs

Presenter: Roland Chemali
Chief Petrophysicist Sperry

Thursday No-29-2012
Kuala Lumpur

HALLIBURTON

Laminated Formations



Evaluation of Laminated Reservoirs

- Image Guided Deconvolution
- Electrical Anisotropy
- Anisotropy Measurement Method Wireline
- Anisotropy Measurement Method LWD
- From Electrical Anisotropy to Saturation
- Magnetic Resonance for Fluid Identification
- Fluid Sampling

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Standard vs. High Resolution Tool Response in Laminated Shaly Sand Reservoirs

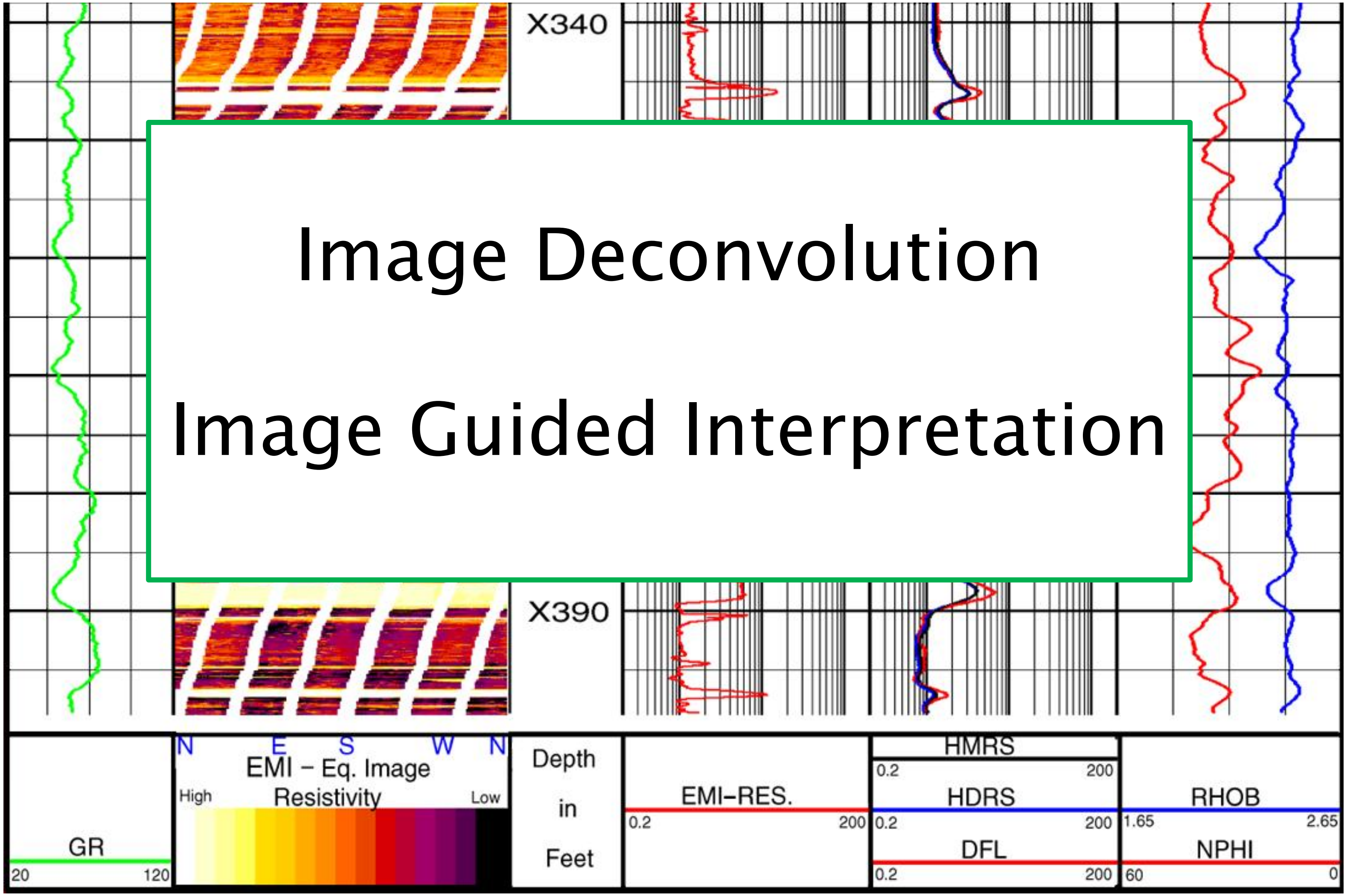
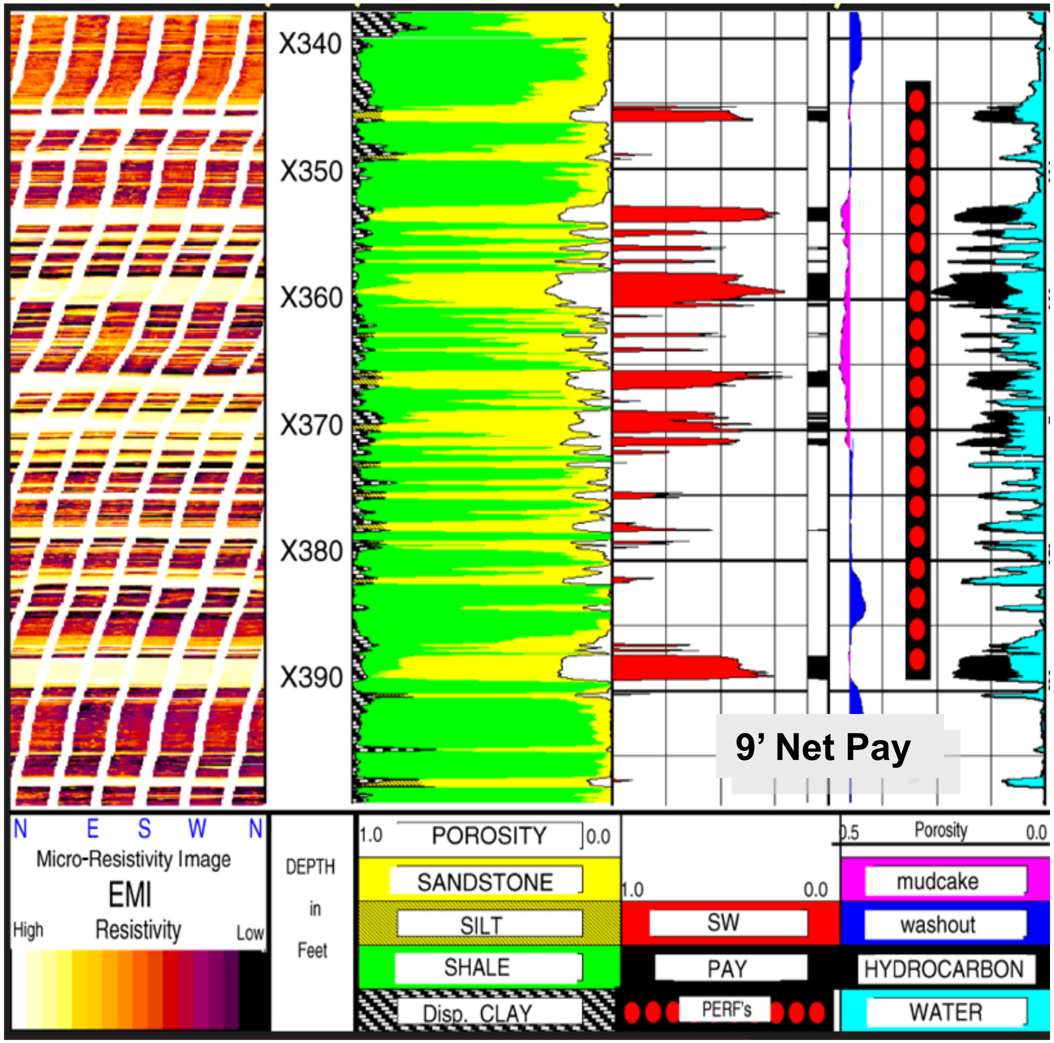


Image Deconvolution

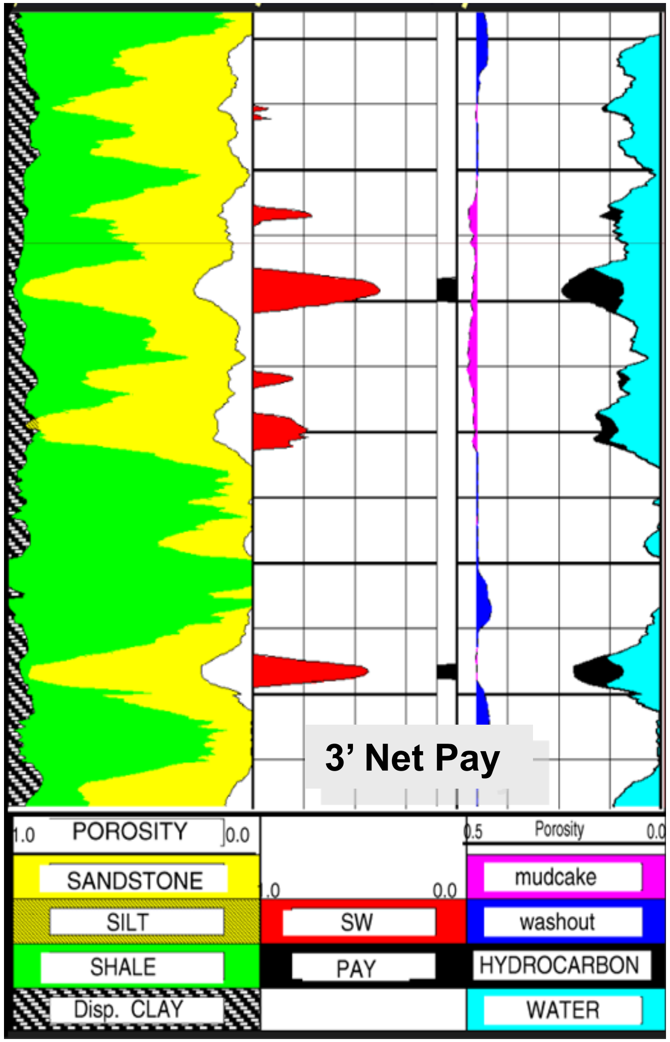
Image Guided Interpretation

SPE 30608

Standard vs. High Resolution Interpretation in Laminated Shaly Sand Reservoirs



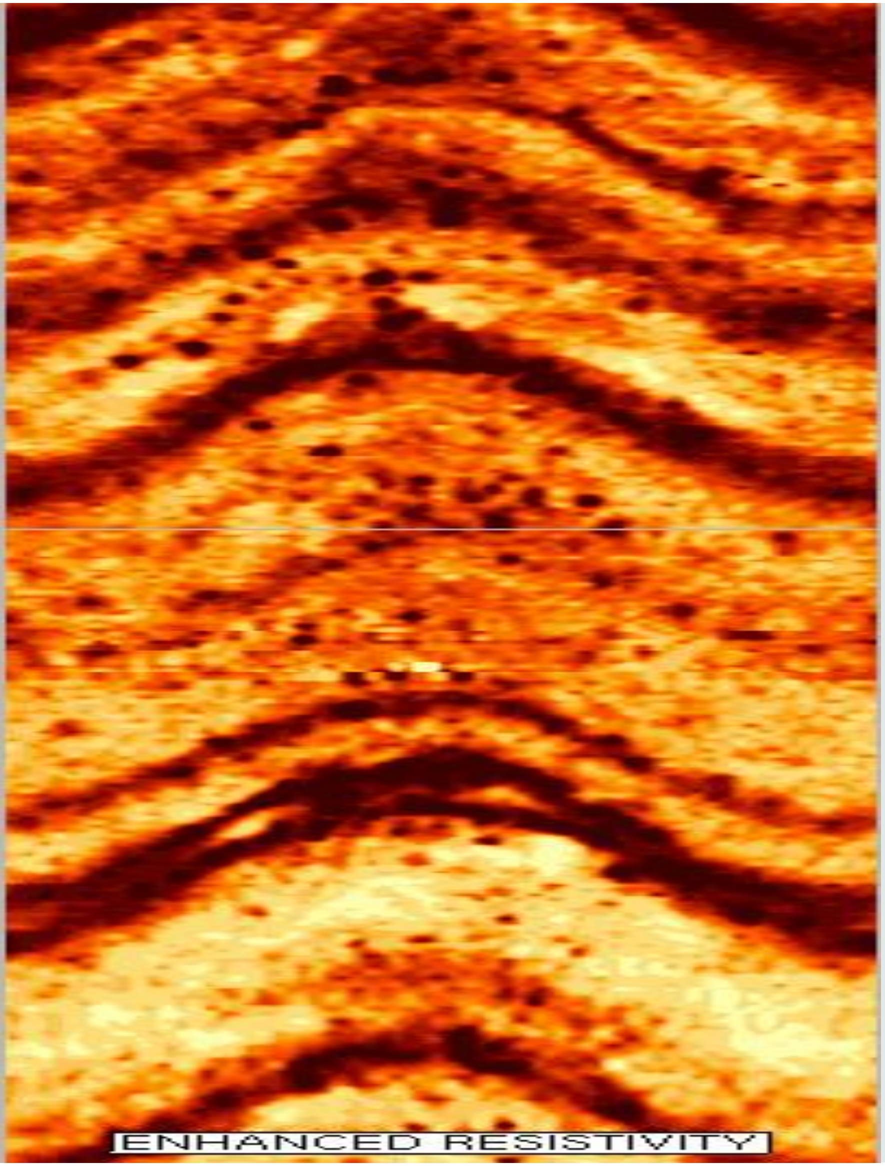
High Resolution



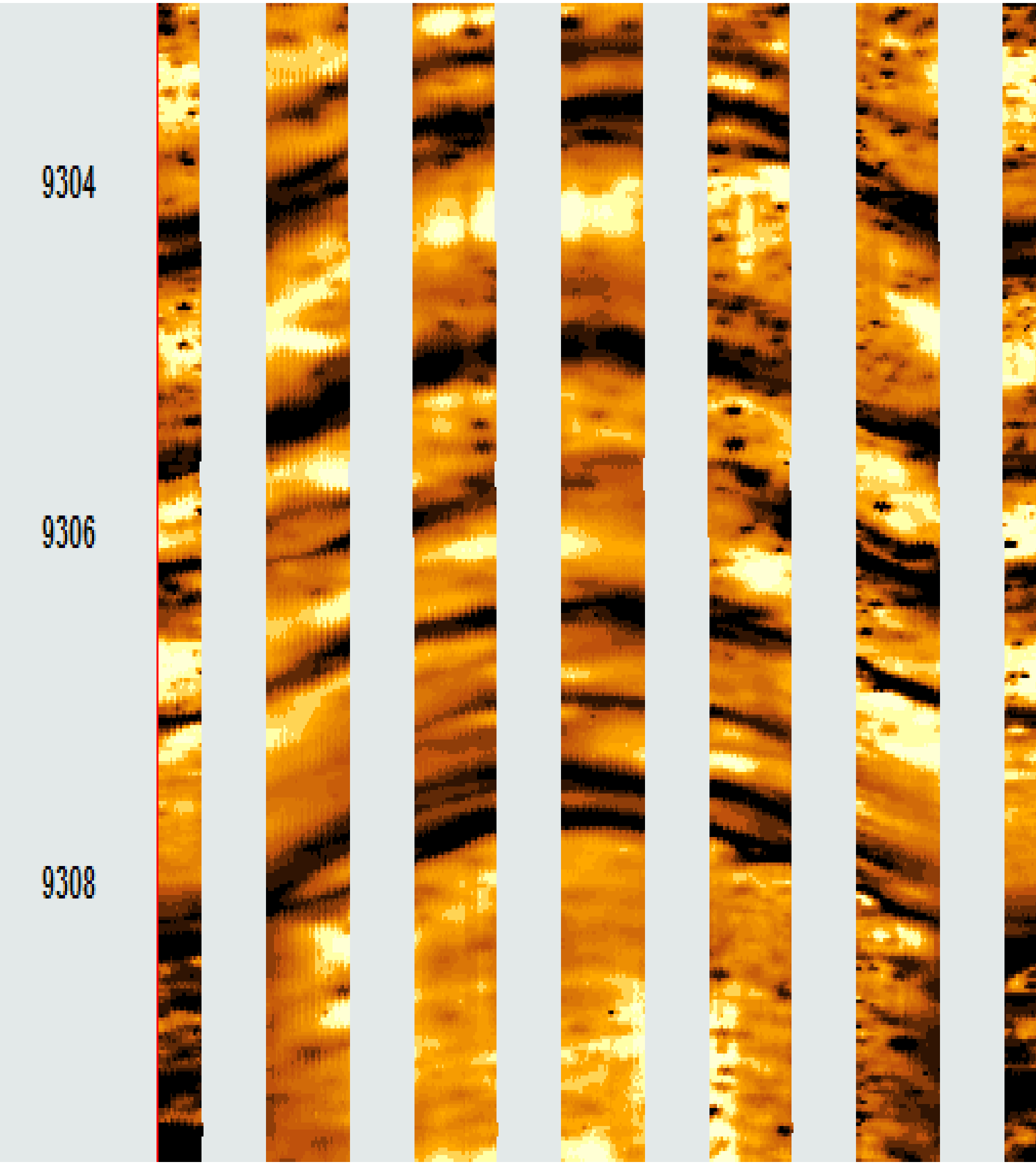
Standard Resolution

SPE 30608

Electrical Imager LWD



Electrical Imager Wireline



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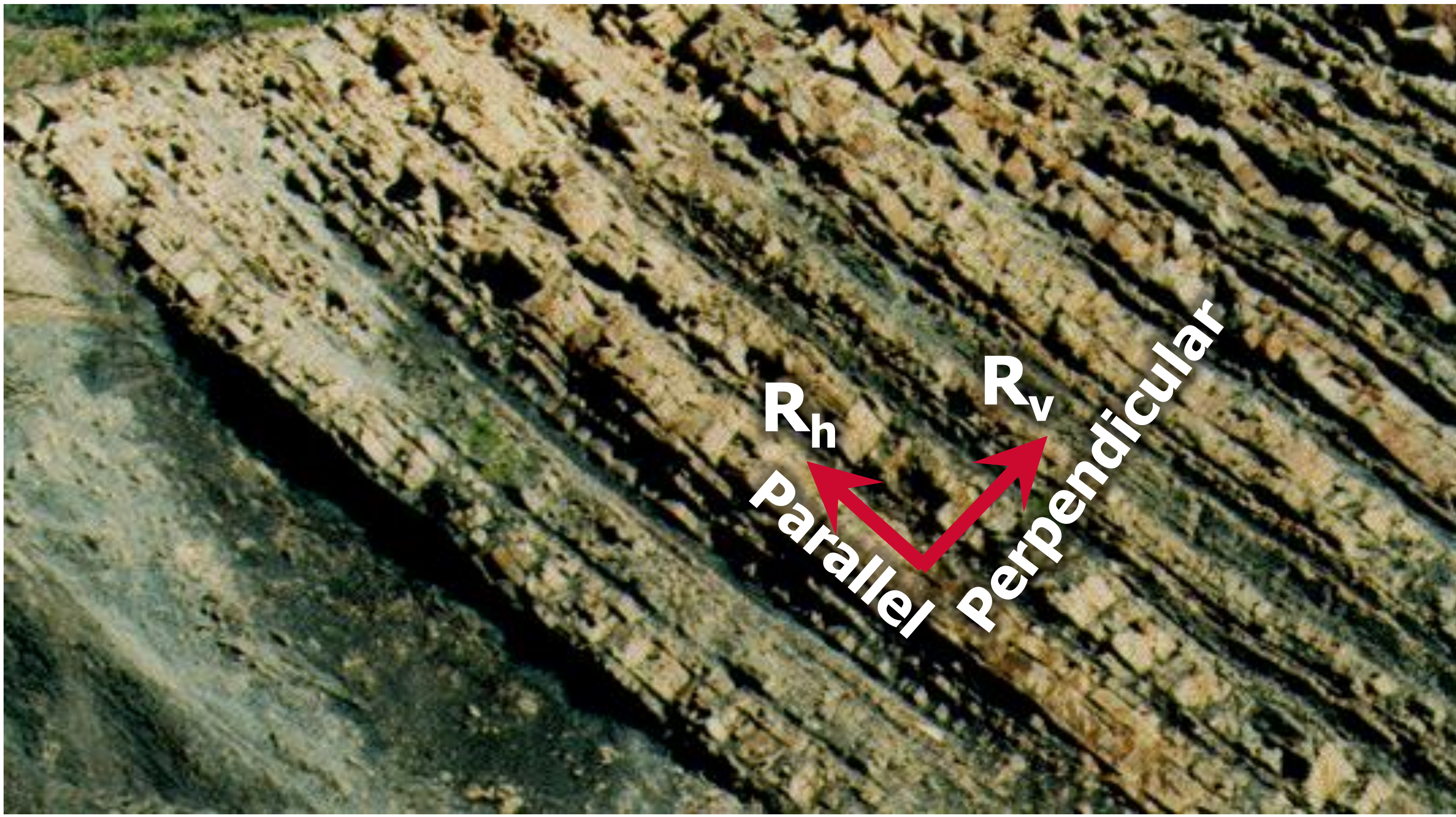
Anisotropy in Turbidites and Laminations

Rv = “Vertical” Resistivity
Rh = “Horizontal” Resistivity

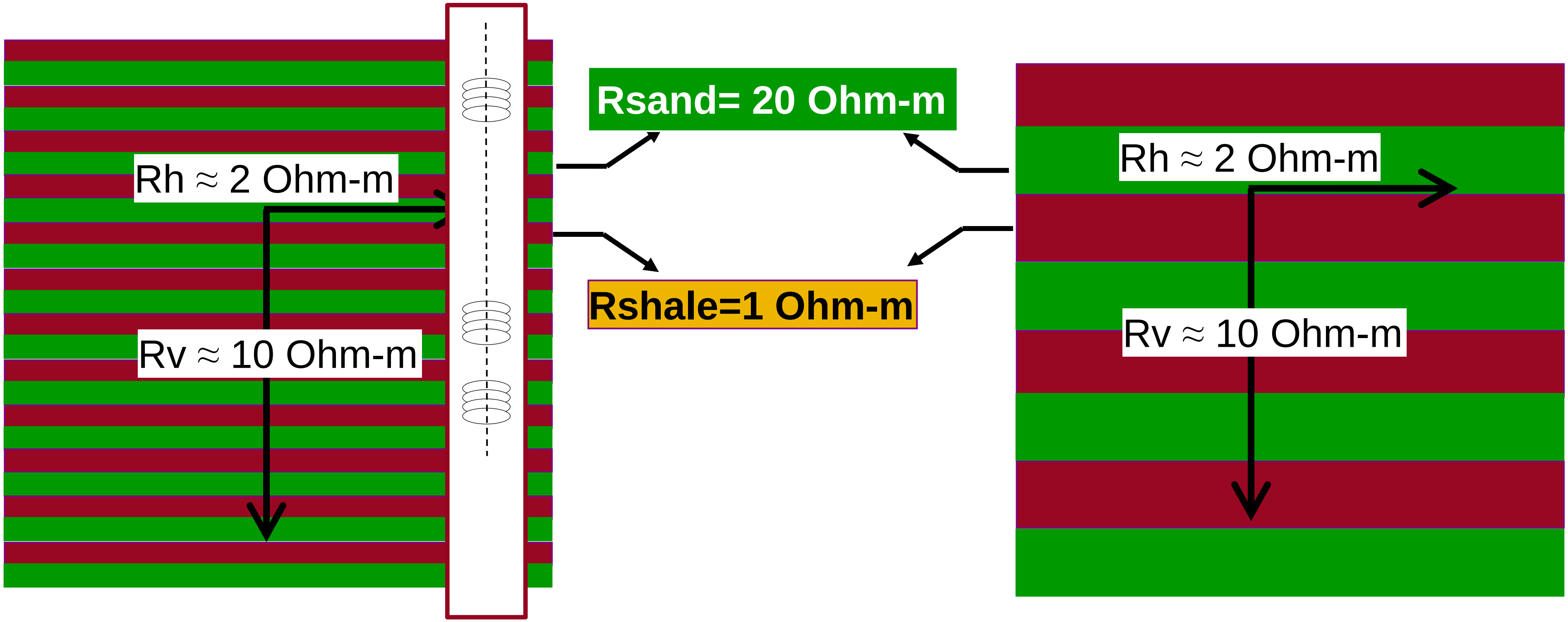
→ Anisotropy Ratio = Rv/Rh

Evaluation of Laminated Reservoirs Through Anisotropy (Shaly Sands, Turbidites..)



Anisotropy in Sand Shale Sequences

The Difference Between Micro-Anisotropy and Macro-Anisotropy is Subjective and Depends On Measuring Instrument



The Vertical Coil Array
Measures Only Rh i.e. 2 Ohm-m i.e. “”Wet”

Anisotropy: Historic Perspective
Anisotropy in the 70's
Paper/Patent for Oil Base Dipmeter

United States Patent [19]

Runge

[54] **TRIPLE COIL INDUCTION LOGGING METHOD FOR DETERMINING DIP, ANISOTROPY AND TRUE RESISTIVITY**

[75] Inventor: **Richard J. Runge,** Anaheim, Calif.

[73] Assignee: **Chevron Research Company,** San Francisco, Calif.

[22] Filed: **Apr. 4, 1973**

[21] Appl. No.: **347,747**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 321,613, Jan. 8, 1973, abandoned, which is a continuation of Ser. No. 795,209, Jan. 30, 1969, abandoned.

[52] **U.S. Cl.** **324/6**
[51] **Int. Cl.** **G01v 3/10,** G01v 3/18
[58] **Field of Search**.................................... 324/6, 8

[56] **References Cited**

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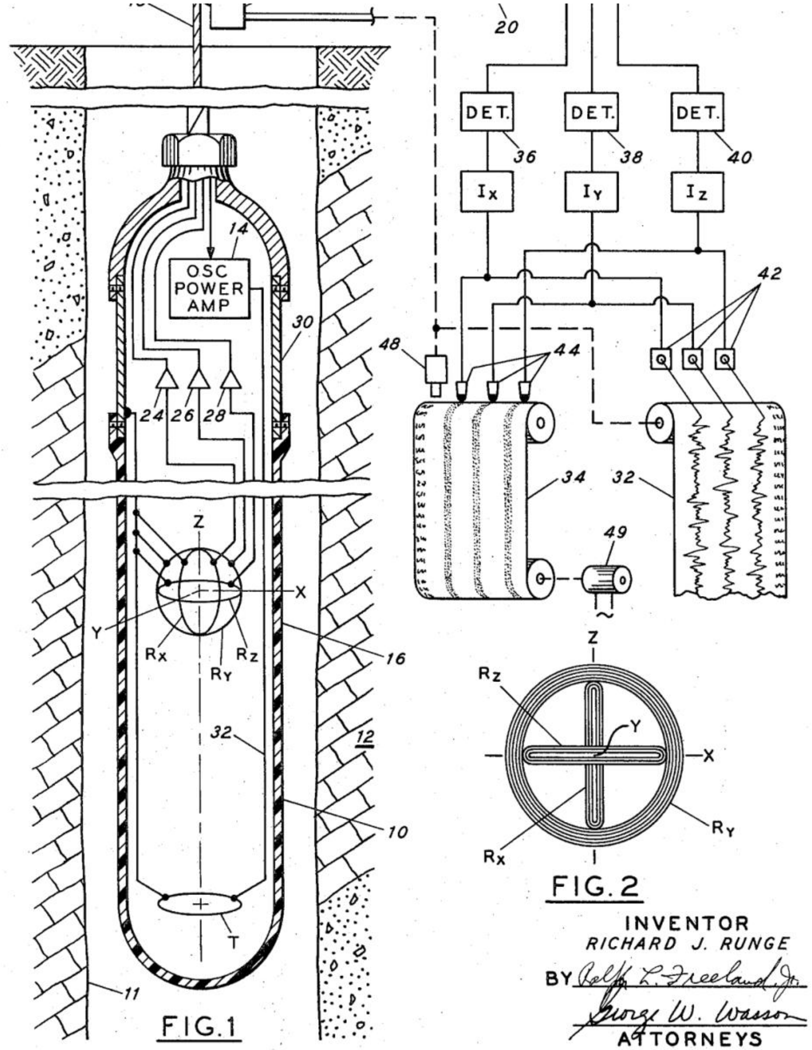
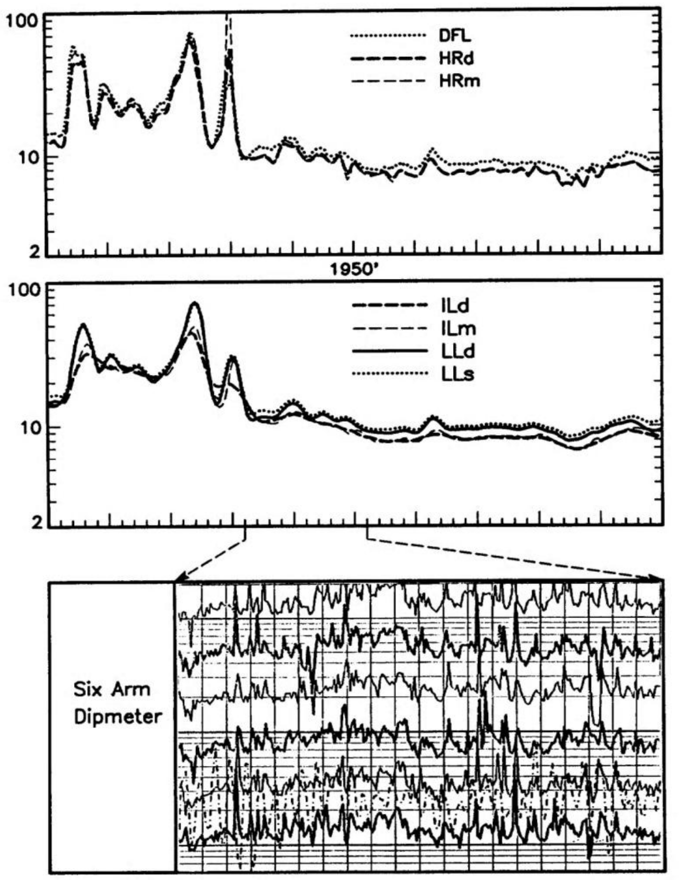


Anisotropy: Historic Perspective

Anisotropy in the 80's

Explains Separation Between Induction and Laterolog
A Nuisance to Contend With



SPWLA Twenty-Eighth Annual Logging Symposium, June 29–July 2, 1987

THE EFFECT OF SHALE ANISOTROPY ON FOCUSED RESISTIVITY DEVICES

by R. Chemali, S. Gianzero and S.M. Su
Gearhart Industries, Inc., Austin Research Center

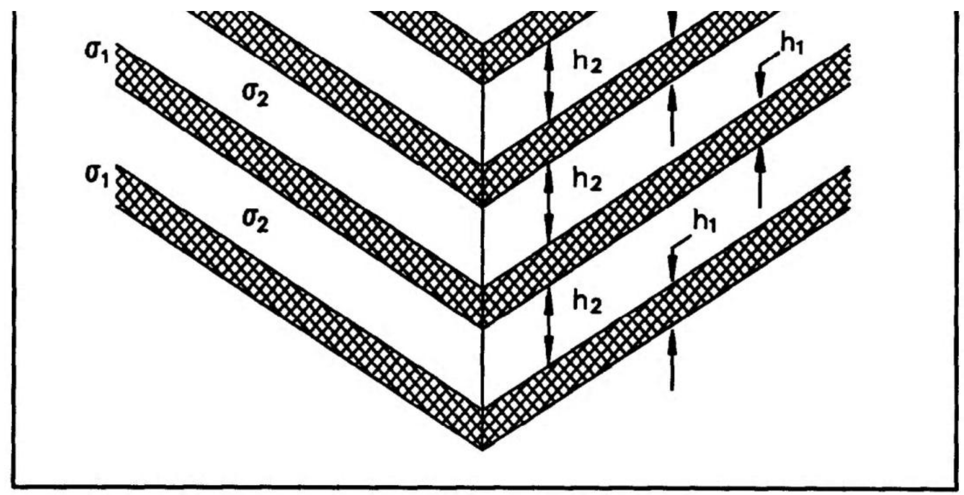


Figure 2b. **Macroscopically Anisotropic Formation.**

In Kuparuk in Alaska, ARCO measured the same turbidite reservoir at different relative dip angles

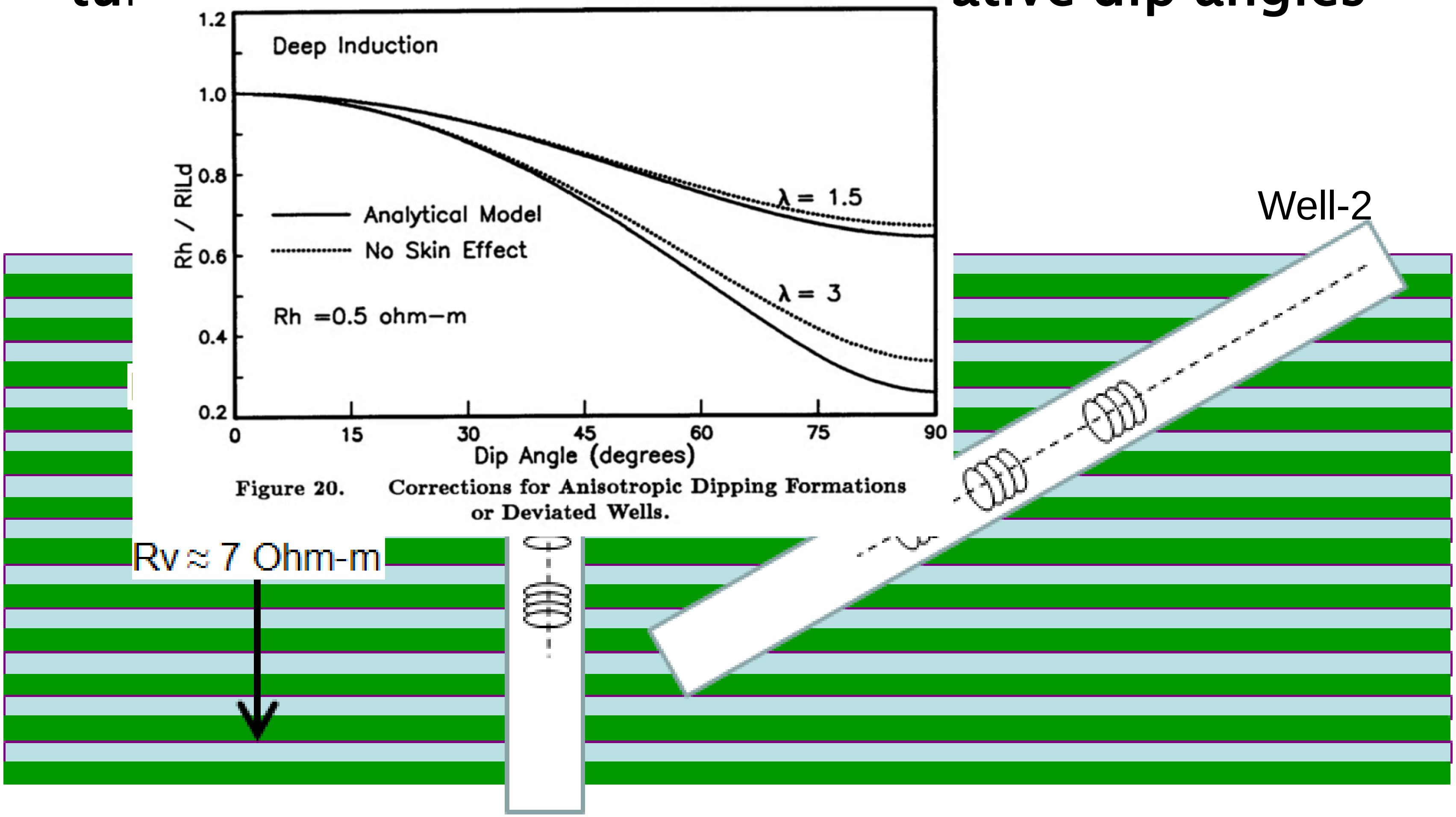


Figure 20. Corrections for Anisotropic Dipping Formations or Deviated Wells.

The Vertical Coil Array
Measures Only Rh i.e. 2 Ohm–m

Sovic, Klein et Al Increase Reserves in Kuparuk and Other Reservoirs

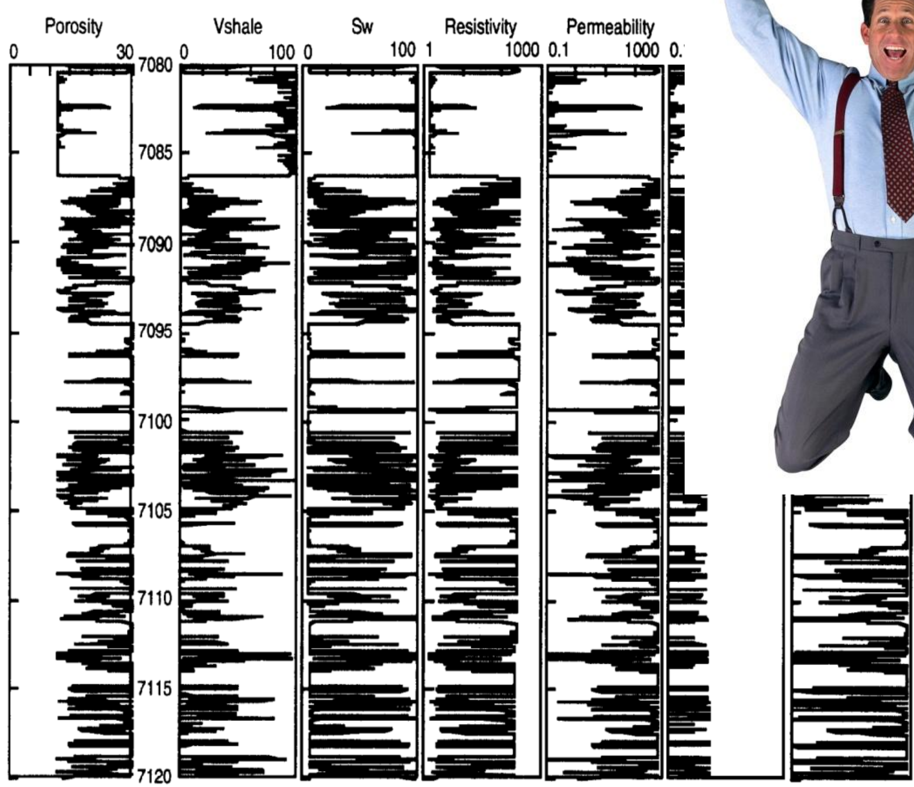


Figure 6. Detailed logs defining the Kuparuk A-Sand model for free water level at 7,200 feet.

SPWLA 37th Annual Logging Symposium, June 16-19, 1996

Thin Bed Mode
Kuparuk A S
KUPARUK RI
NORTH SLOI

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J. D. Klein and P
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SPWLA 42nd Annual Logging Symposium, June 17-20, 2001

IMPACT OF MULTICOMPONENT INDUCTION TECHNOLOGY ON A DEEPWATER TURBIDITE SAND HYDROCARBON SATURATION EVALUATION

R.A. Mollison, O.N. Fanini, B.F. Kriegshäuser, L. Yu, *Baker Atlas*, G. Ugueto, Shell Exploration and Production, and J. van Popta, *Shell EP Technology*

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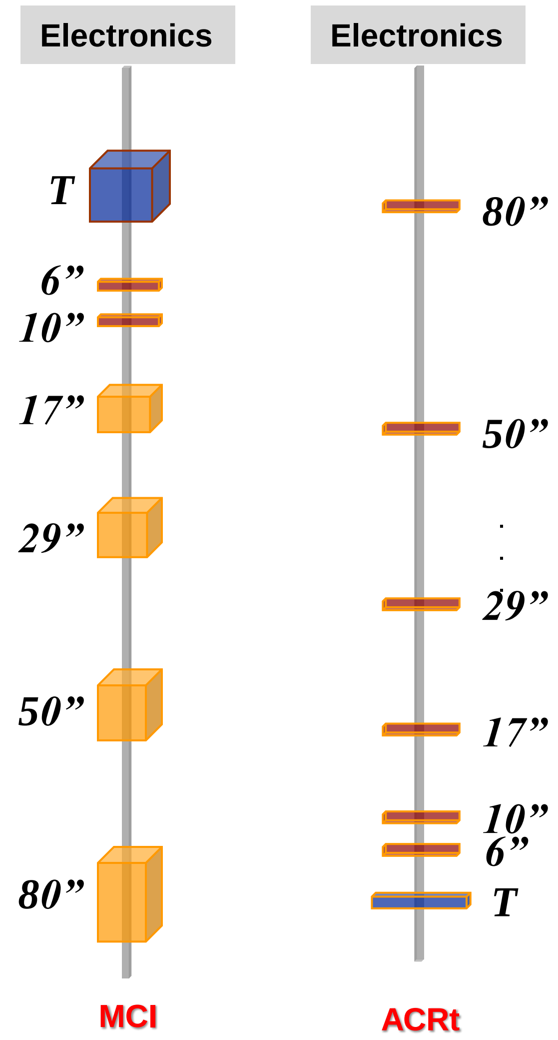
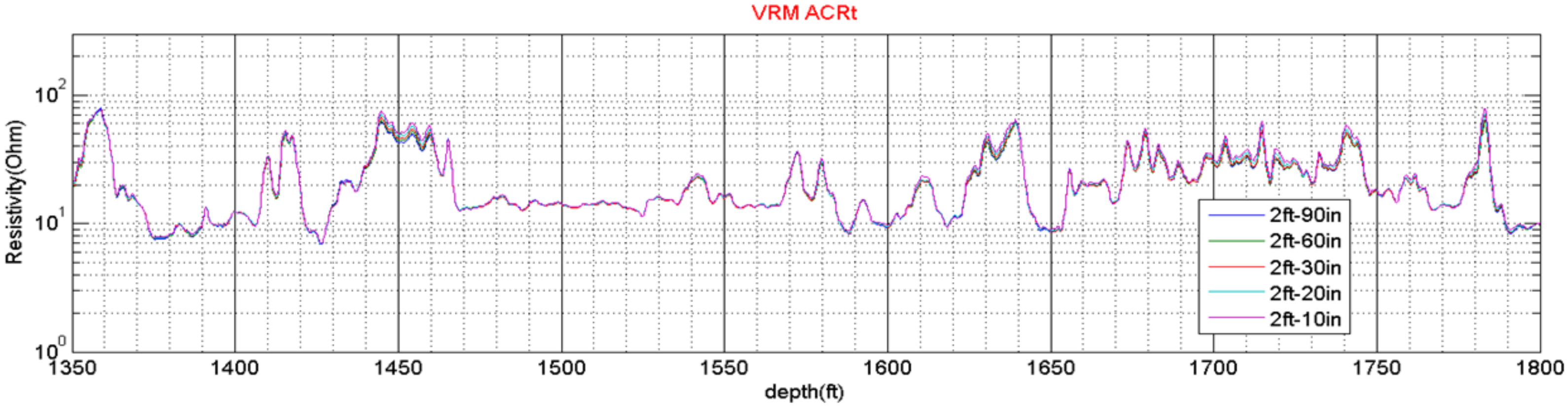
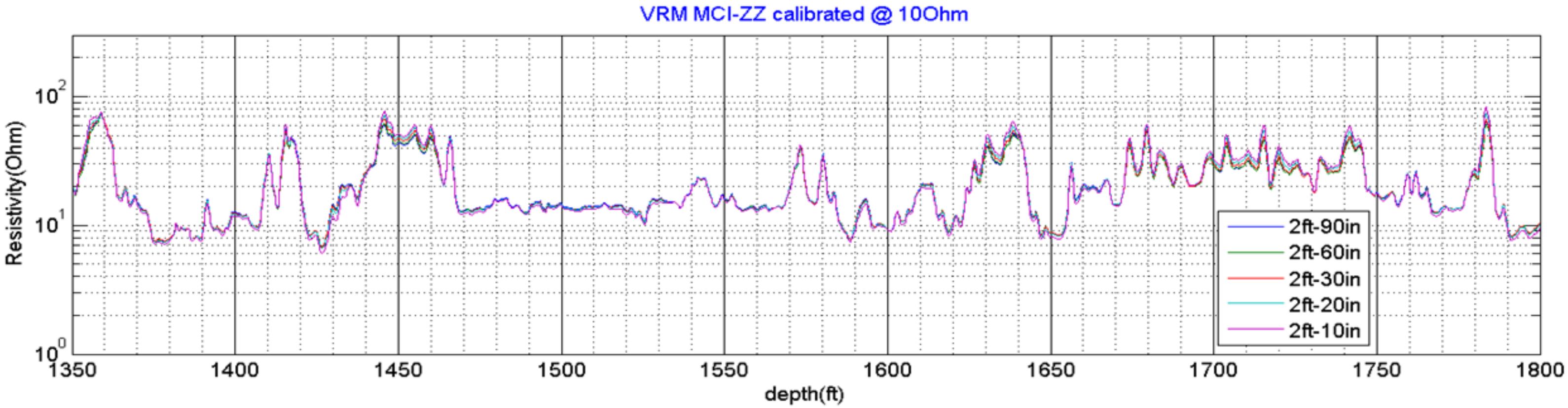
Multi-Component Induction Hardware Description

- 1 Co-located Transmitter triad
- 2 standard z short spacing coils
  - Same as ACRt
    - 6”, 10”
- 4 Co-located Receiver triads
  - Receiver Triad Main and bucking coils
  - Same spacings as ACRt
    - 17”, 29”, 50”, 80”
  - Multi-frequency operation
    - MCI : 12, 36, **60**, 84 kHz
    - ACRt: 12, 36, **72** **kHz**

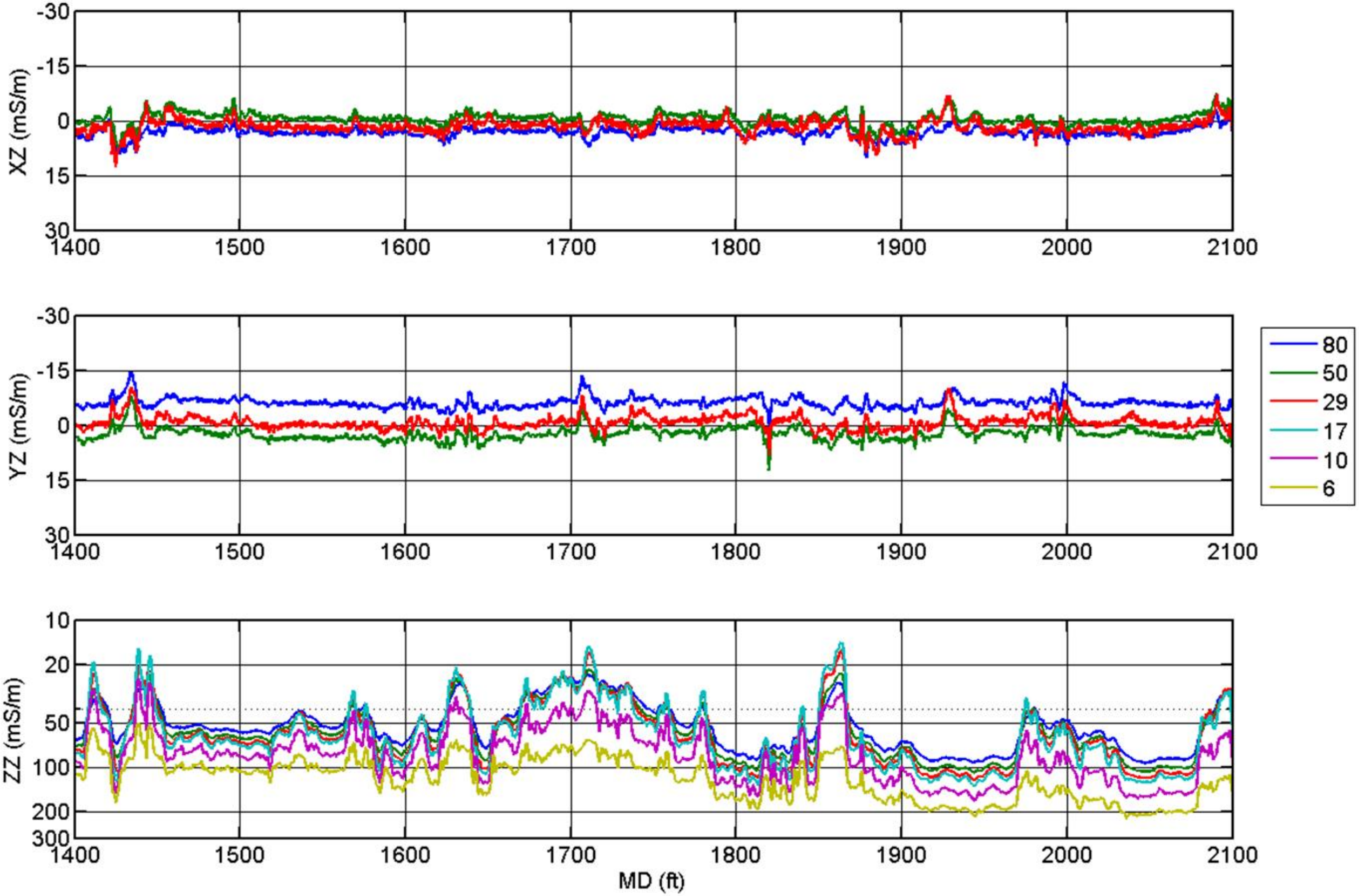


Test well: Comparison Between Multi-Component Induction and Single Component Induction Responses

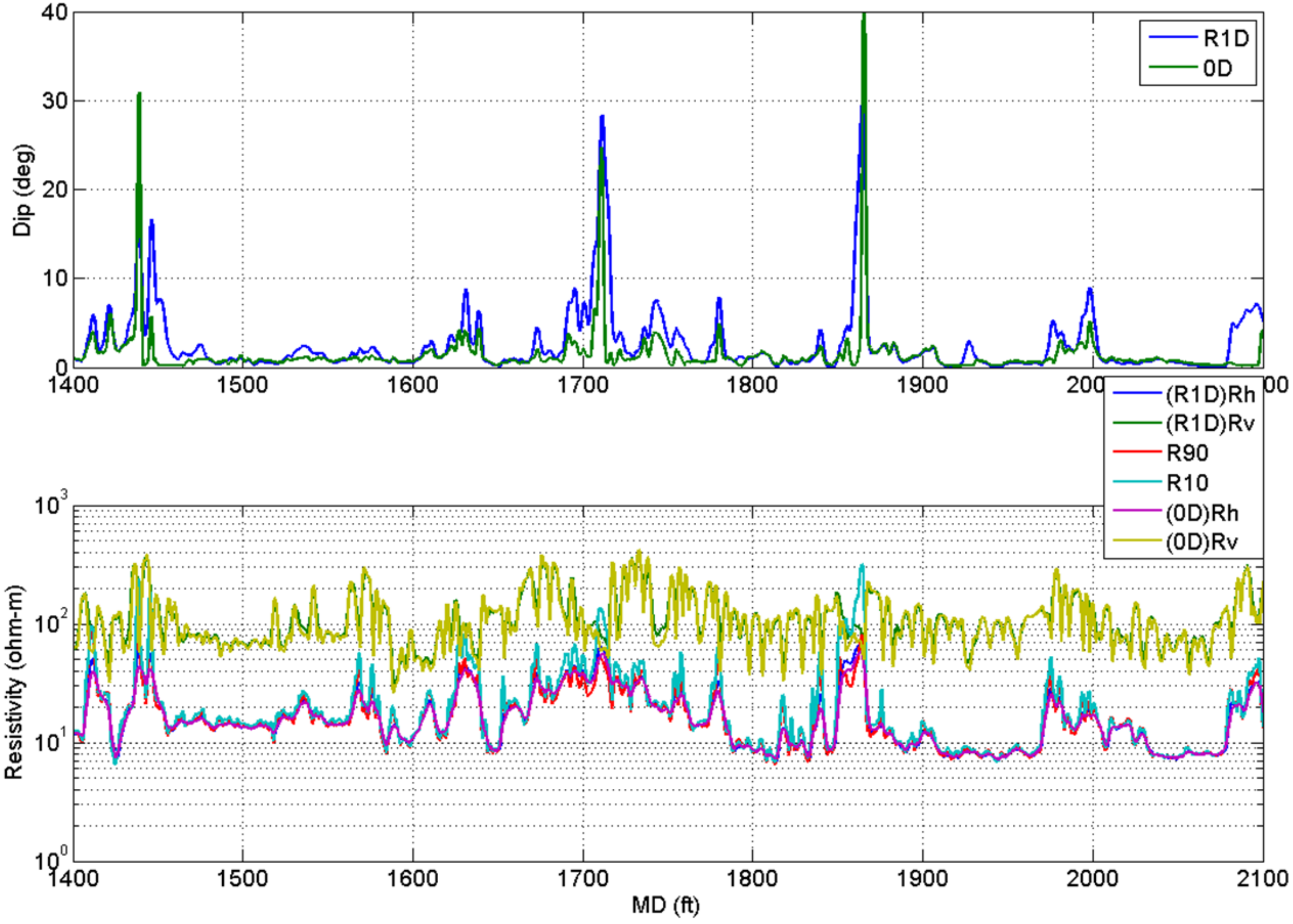




Additional Components in Test Well: XZ and YZ



Inverted Results From Multi-Component Induction



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Measuring Electrical Anisotropy with LWD

United States Patent [19] | [11] **Patent Number: 6,163,155**

Bittar | [45] **Date of Patent: Dec. 19, 2000**

[54] **ELECTROMAGNETIC WAVE RESISTIVITY TOOL HAVING A TILTED ANTENNA FOR DETERMINING THE HORIZONTAL AND VERTICAL RESISTIVITIES AND RELATIVE DIP ANGLE IN ANISOTROPIC EARTH FORMATIONS**

[75] Inventor: **Michael S. Bittar**, Houston, Tex.

[73] Assignee: **Dresser Industries, Inc.**, Dallas, Tex.

97118854 10/1997 European Pat. Off. G01V 3/30

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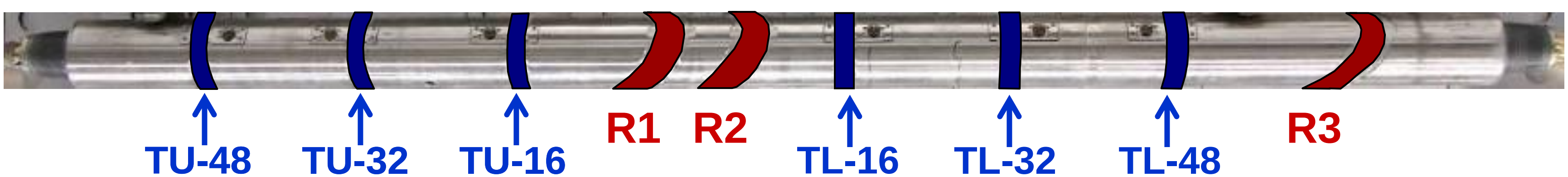
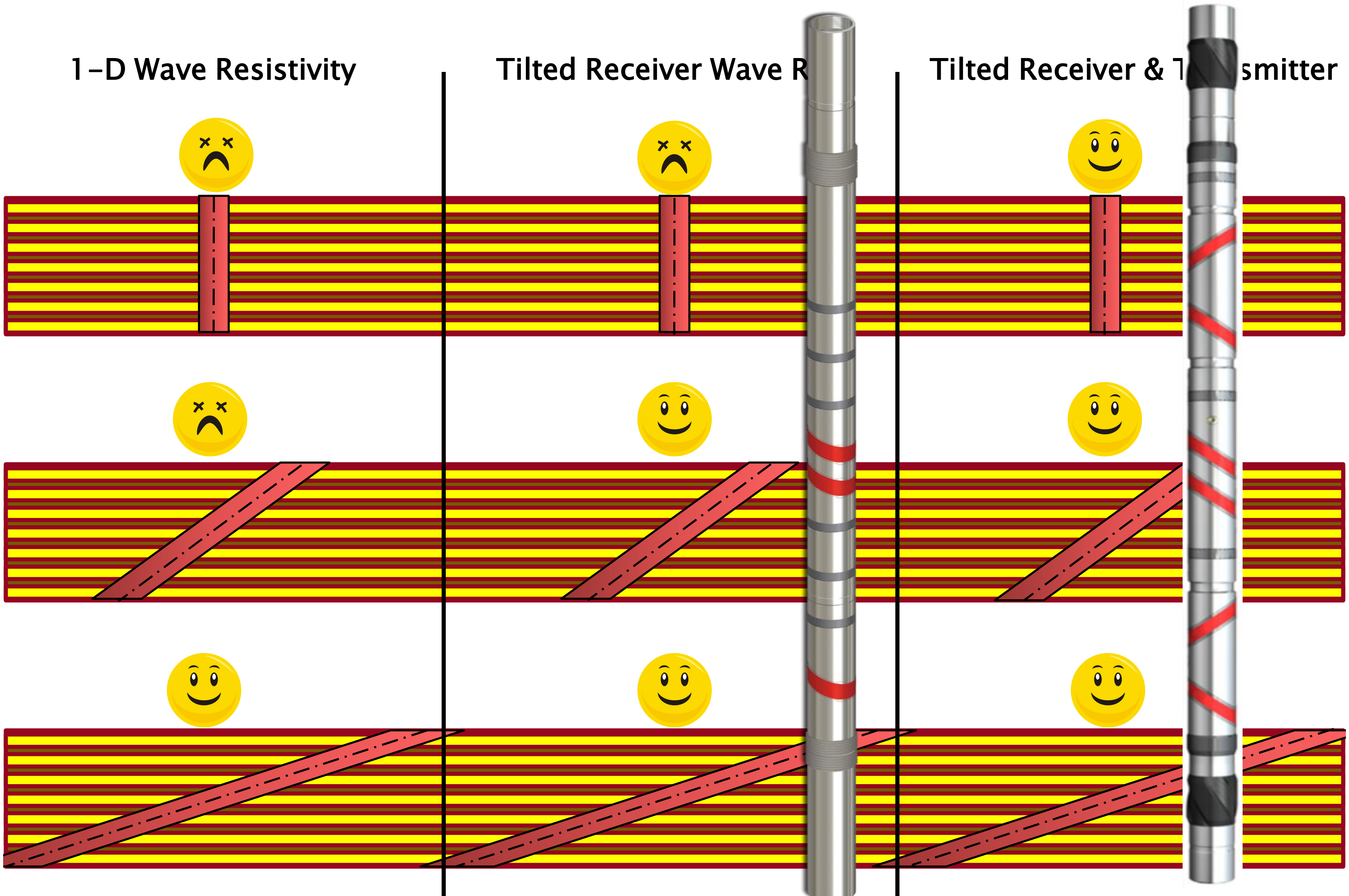
Zhu, T. and L. Brown, "Two–dimensional Velocity Inversion and Synthetic Seismogram Computation," Geophysics, vol. 52, No. 1, Jan. 1987; p. 37–49.

Bittar, M. and P. Rodney, "The Effects of Rock Anisotropy on MWD Electromagnetic Wave Resistivitiy Sensors," The Log Analyst, Jan.–Feb. 1996, p. 20–30.

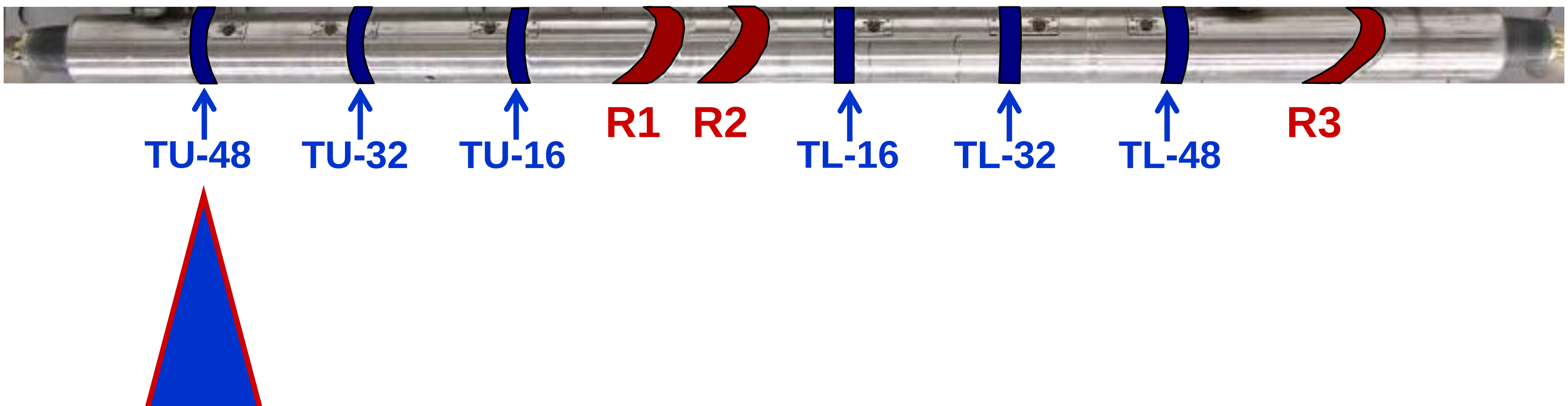
Hagiwara, T., "A New Method to Determine Horizontal-



Determination of Electrical Anisotropy With Wave Resistivity LWD

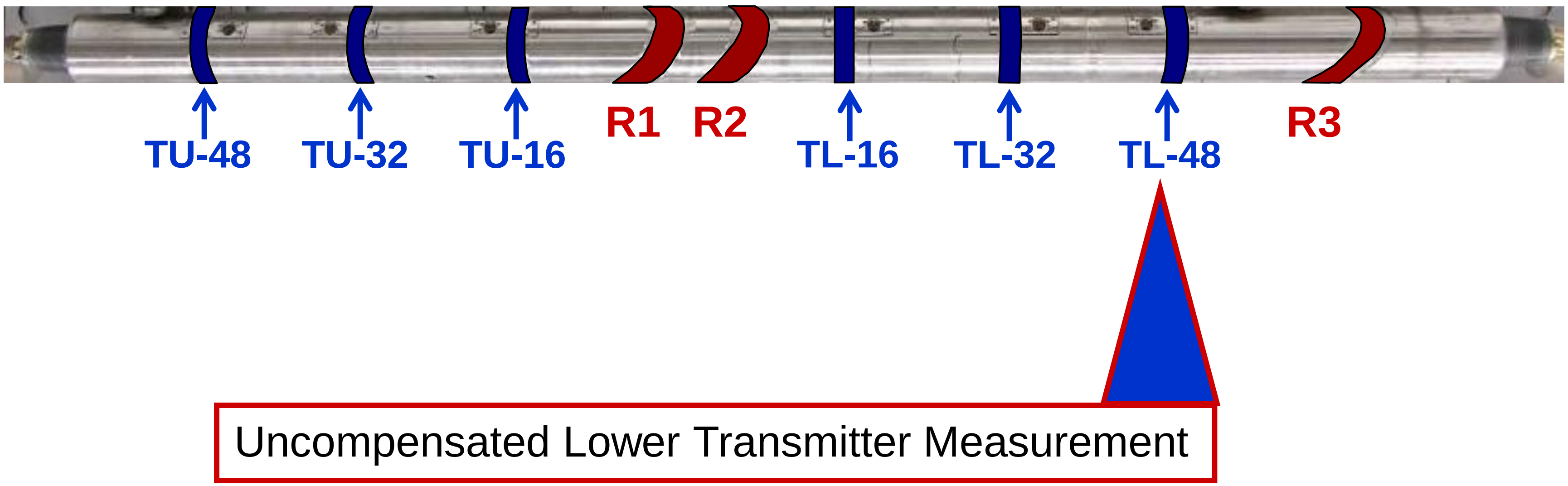


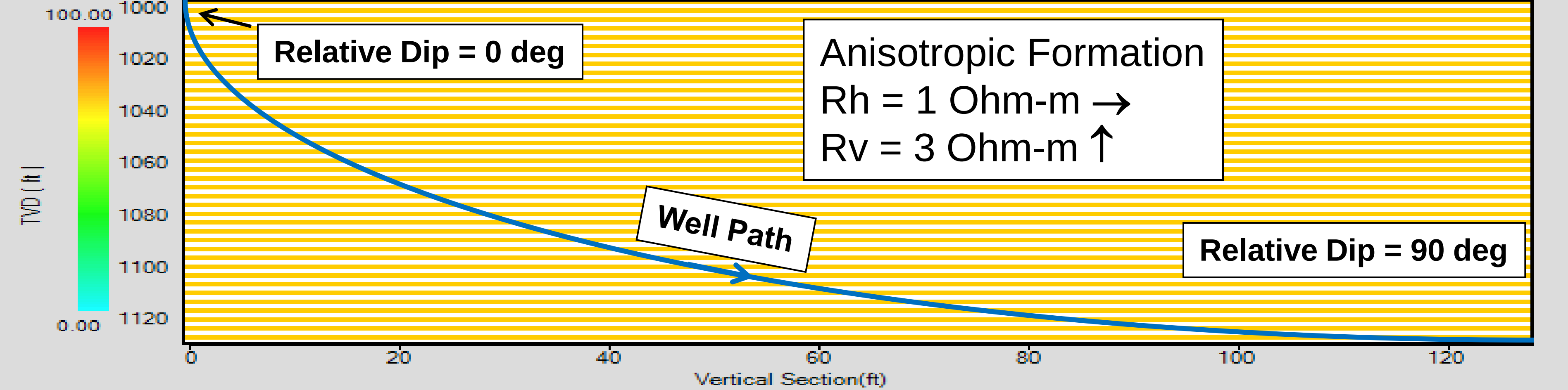
Azimuthal Deep Resistivity LWD for Anisotropy



Uncompensated Upper Transmitter Measurement

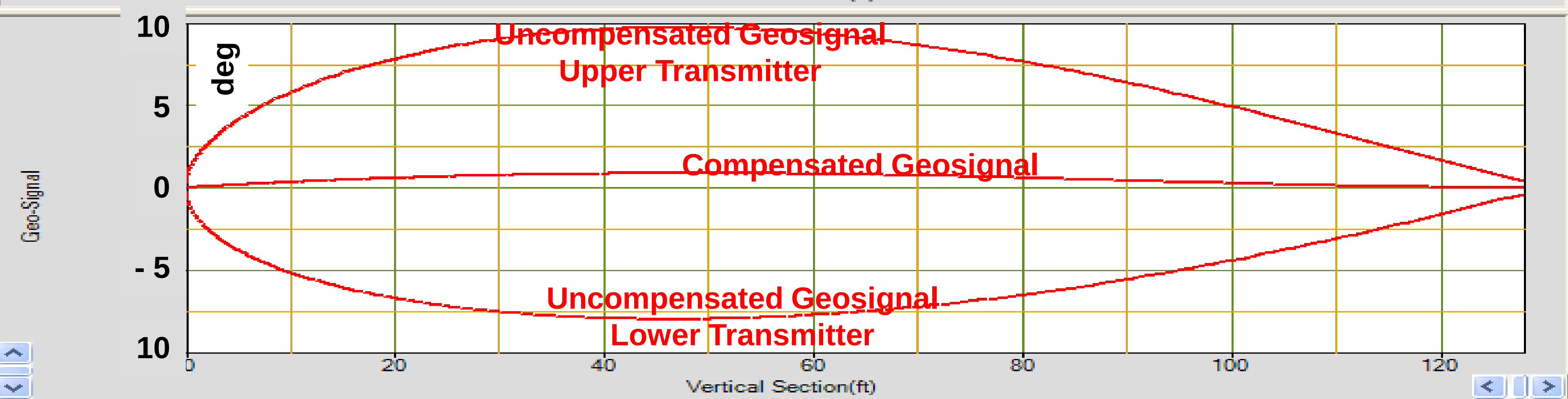
Azimuthal Deep Resistivity LWD For Anisotropy



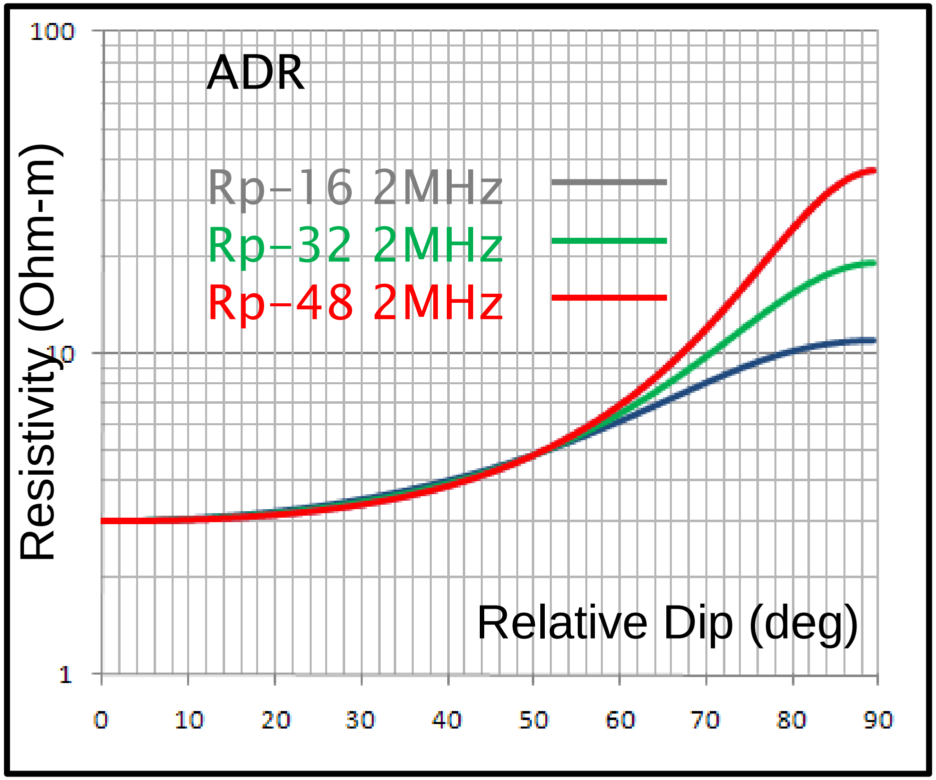


Anisotropy Determination with LWD ADR

At Moderate Relative Dip (cont…)

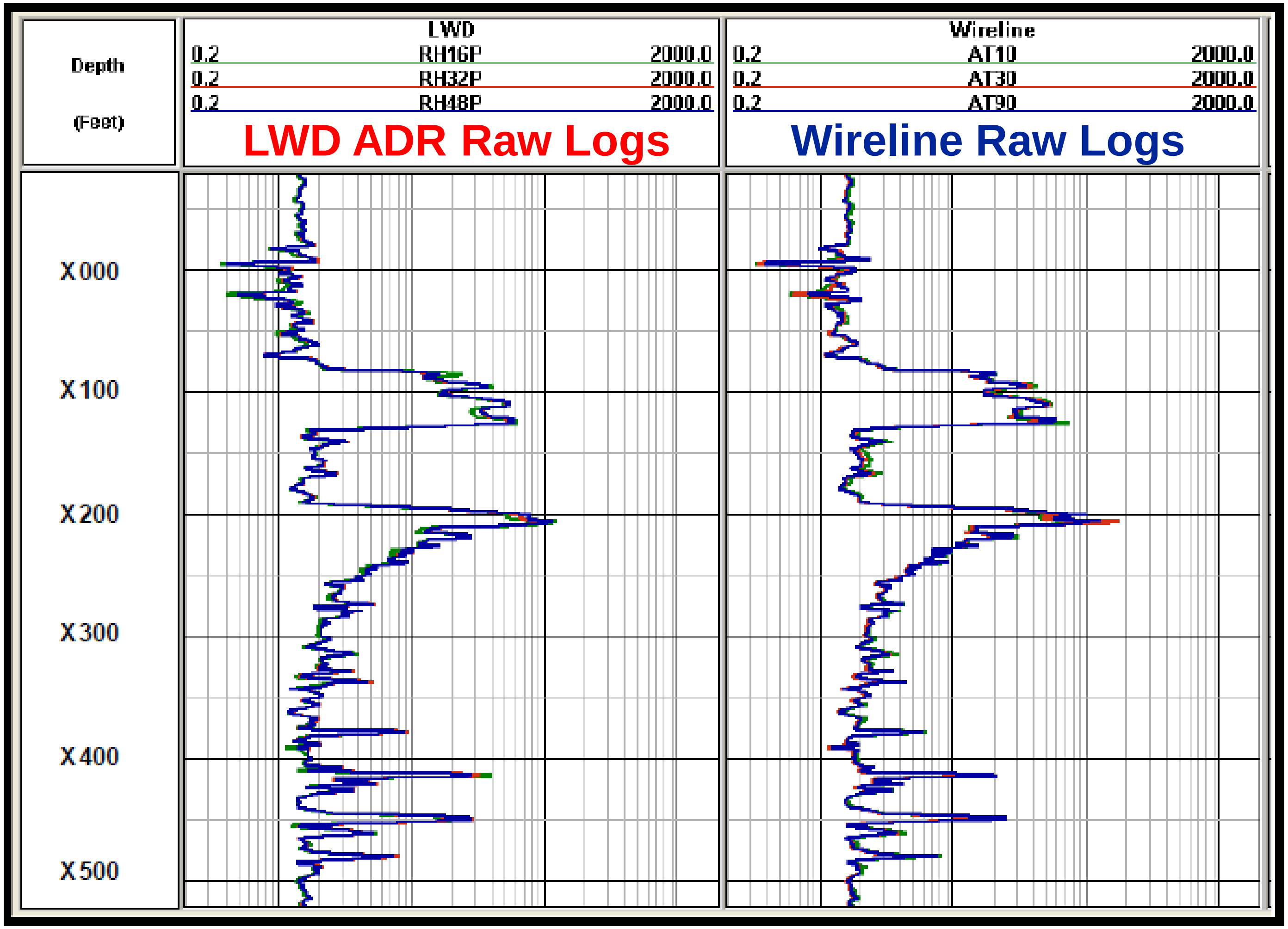


Anisotropy Determination with LWD ADR At Very High Relative Dip Rh = 3 Ohm-m, Rv = 20 Ohm-m



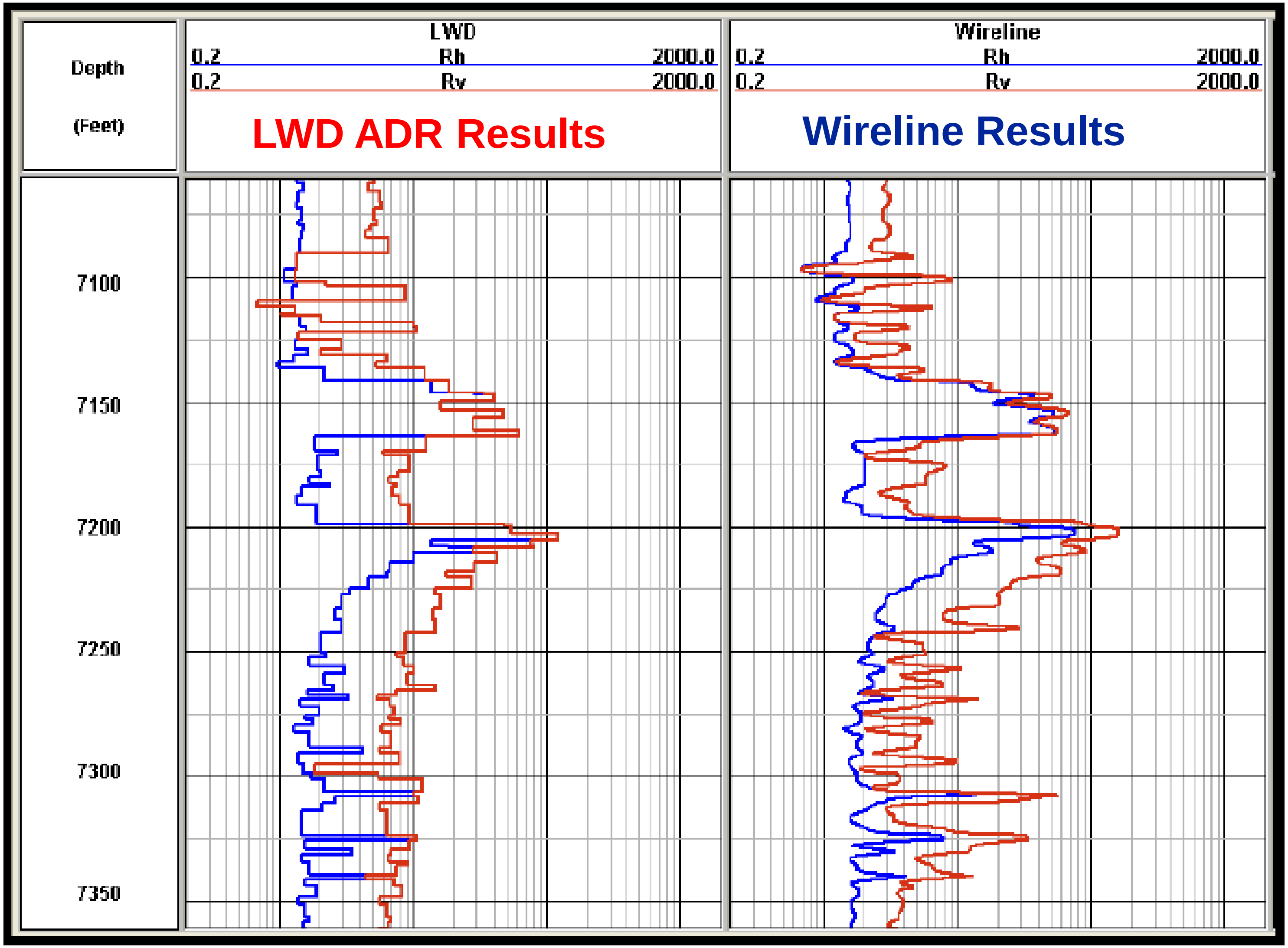
Rv, Rh, From LWD ADR

Raw Data



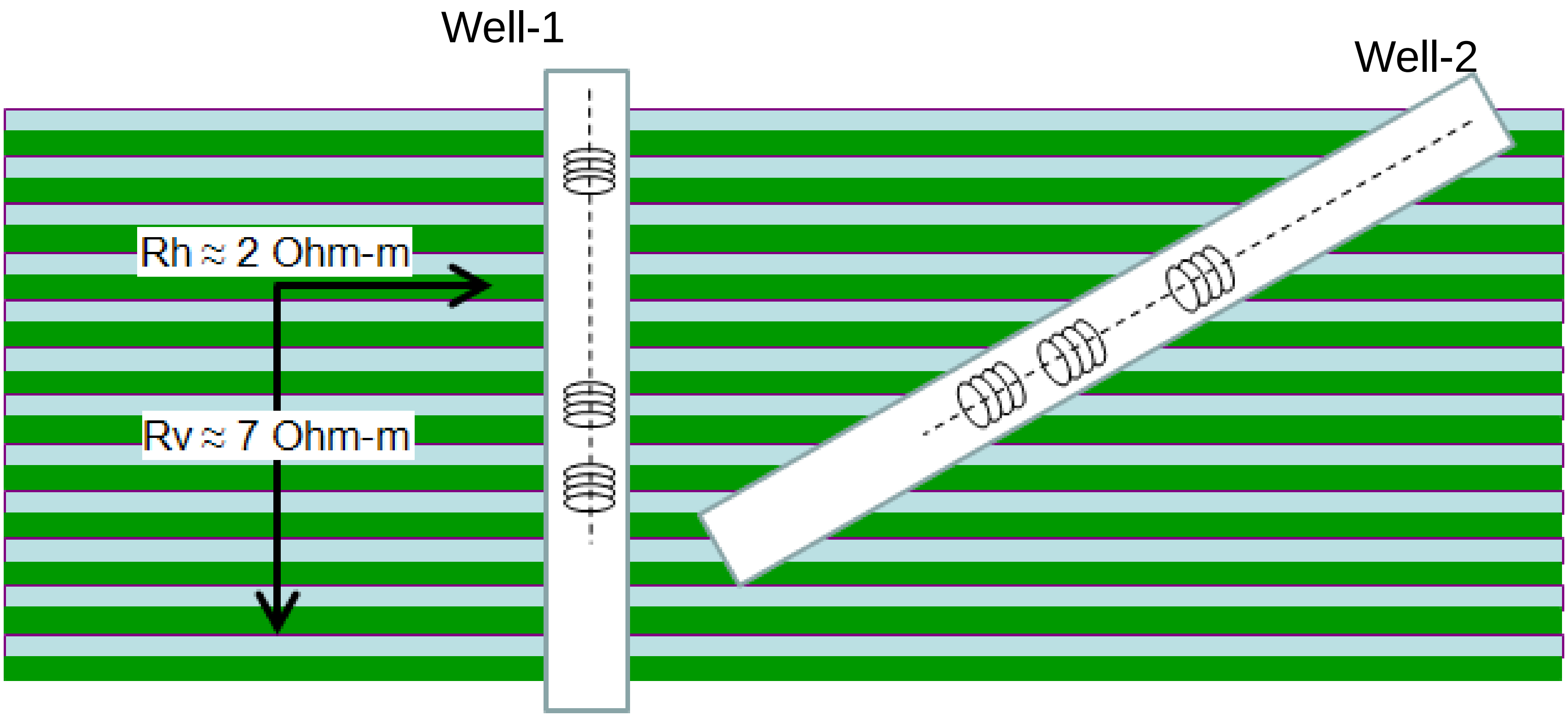
SPE-123890

Rv, Rh, From LWD ADR Processed Results



SPE-123890

In a Field In Alaska We Measure the Same Formation At Different Relative Dip Angles

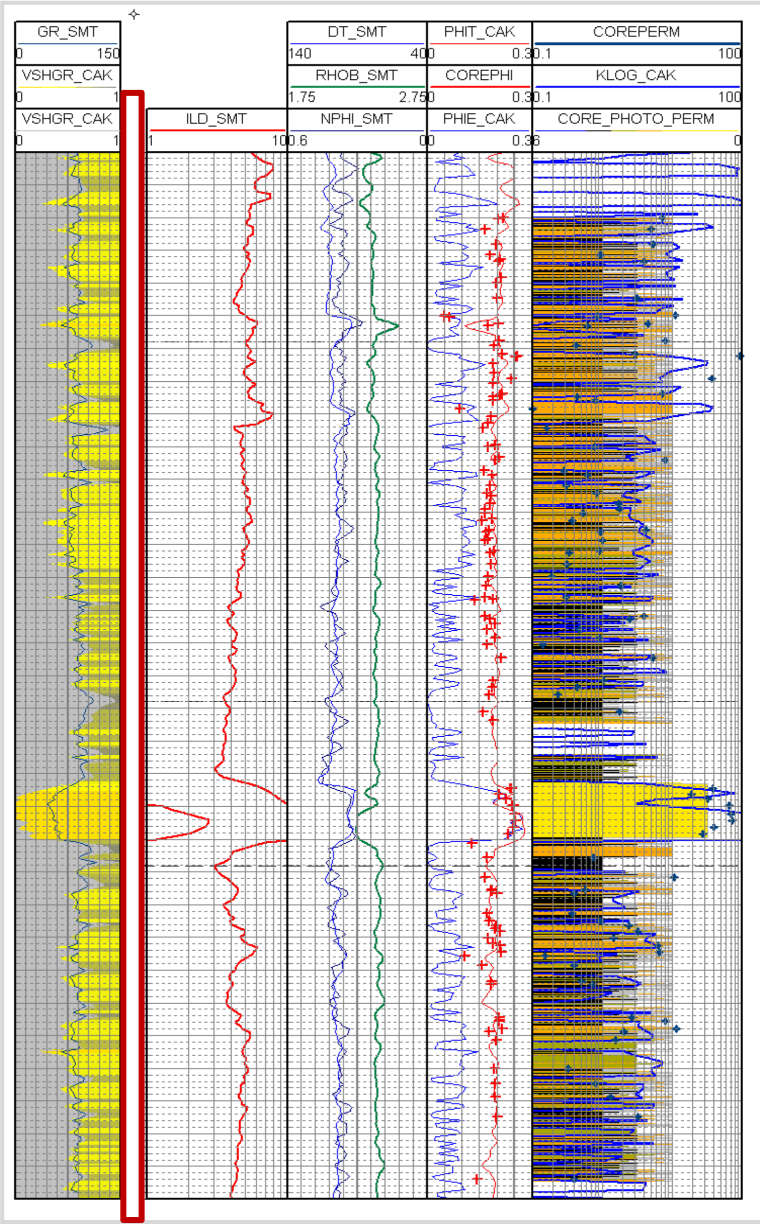


The Vertical Coil Array
Measures Only Rh i.e. 2 Ohm-m

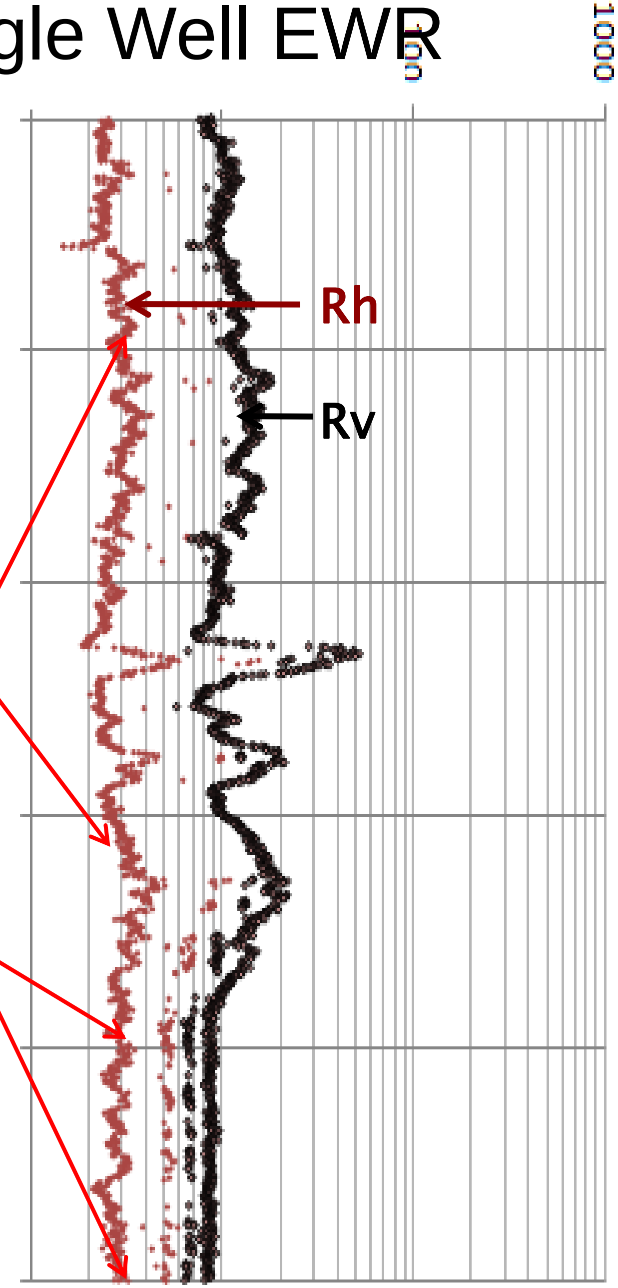
Estimating Vsh-lam, and Rsand

Rsh-h=2 Ohm-m
Rsh-v = 7 Ohm-m
Rv, Rh obtained from previous joint inversion

Vertical Well

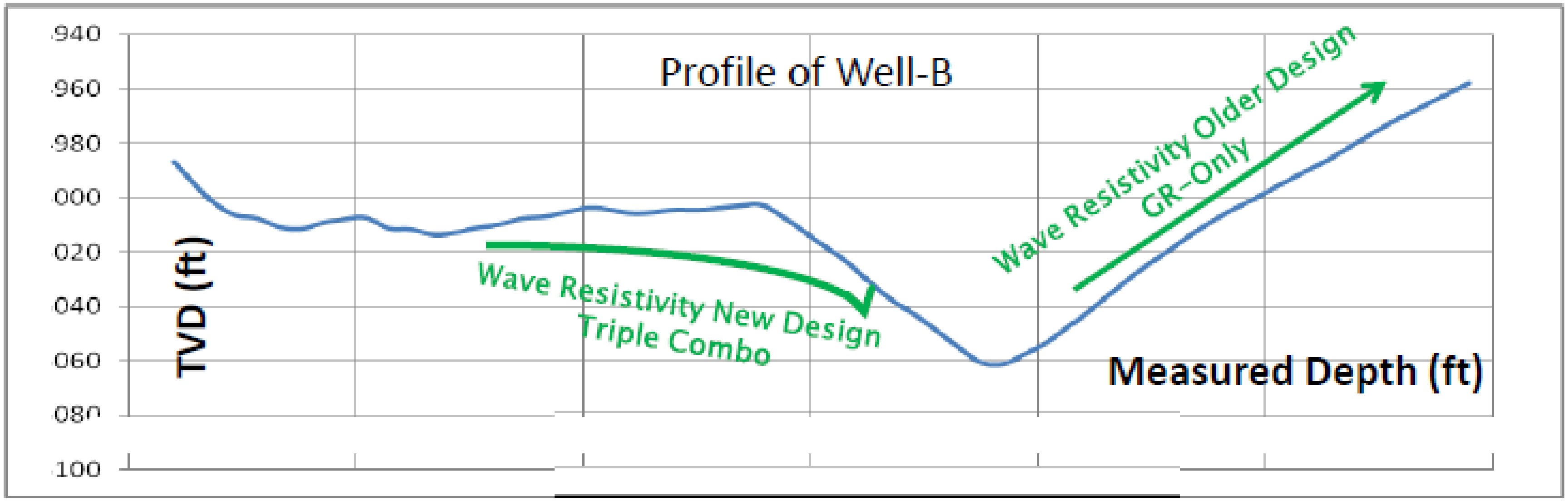


High Angle Well EWR

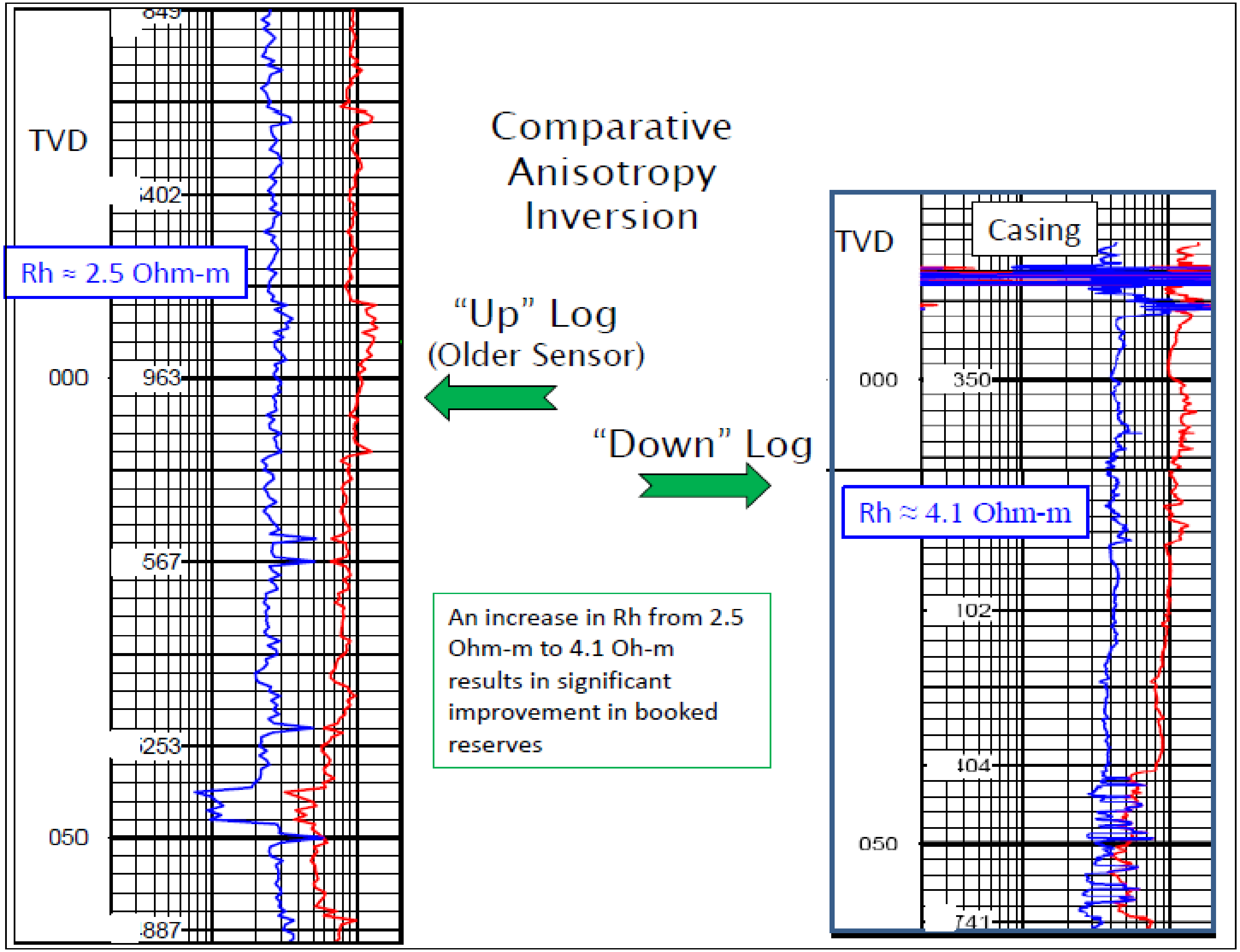


In the zones of interest Rh varies between 4 ohm-m and 6 ohm-m

Comparative Performance of Azimuthal and Non-Azimuthal LWD Resistivity Sensors



Comparative Performance of Azimuthal and Non-Azimuthal LWD Resistivity Sensors



An increase in Rh from 2.5 Ohm-m to 4.1 Oh-m results in significant improvement in booked reserves

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From Rv, Rh, and Rshale
Get Rsand & Vshale

For a laminated sand/shale sequence, the vertical resistivity, Rv, can be expressed as:

$$Rv = (1 - Vsh) \cdot Rsand + Vsh \cdot Rshale \qquad (1)$$

Similarly, the horizontal resistivity, Rh, can be expressed as:

$$Rh = \frac{Rsand \cdot Rshale}{(1 - Vsh) \cdot Rshale + Vsh \cdot Rsand} \qquad (2)$$

Solving equations (1) and (2) for Rsand, in terms of Rv, Rh, and Rshale, reduces to:

$$Rsand = Rh \cdot \left(\frac{Rv - Rshale}{Rh - Rshale} \right) \qquad (3)$$

Assume water saturation can be expressed as:

$$Sw = \frac{1}{\Phi} \cdot \sqrt{\frac{Rw}{Rt}} \qquad (4)$$

Example:

Assume Rw = 0.05 Ω-m and Φ = 30%. Also, assume shale lamina's resistivity, Rshale, = 1.0 Ω-m.

If the deep phase shift resistivity of 3.8 Ω-m is used as Rt in equation (4), then:

$$Sw = 38\%$$

If anisotropy processing is used, then:

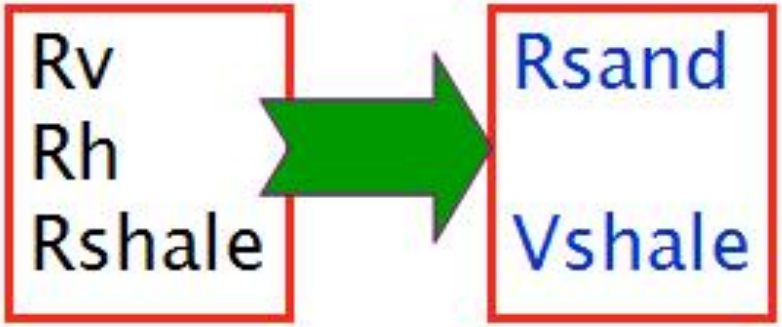
$$Rv = 5.0\ \Omega\text{-m}$$
$$Rh = 1.8\ \Omega\text{-m}$$

and substituting in Equation (3) along with Rshale produces:

$$Rsand = 9.0\ \Omega\text{-m}$$

Using Rsand as Rt in Equation (4), then:

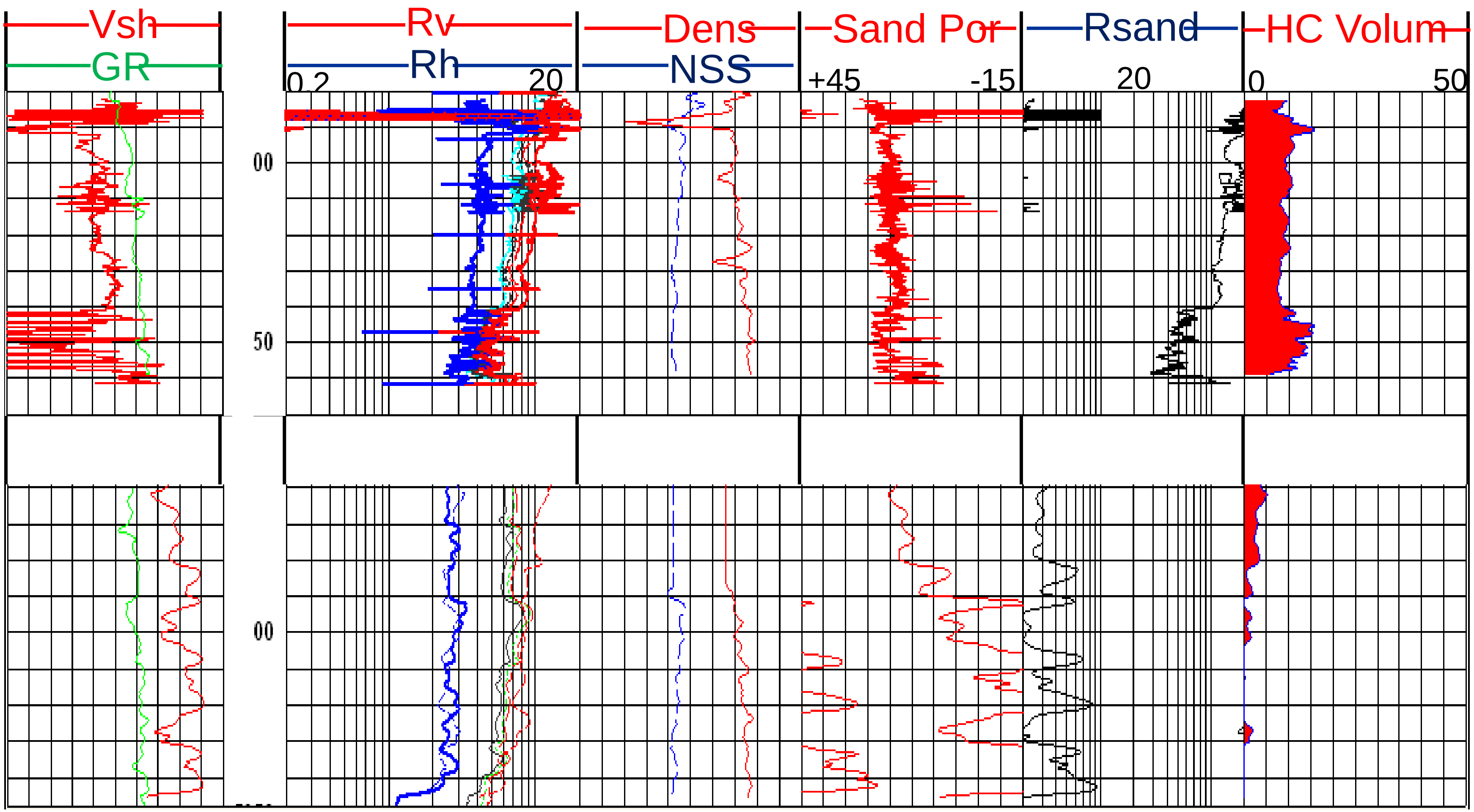
$$Sw = 25\%$$



Algorithms Available from:

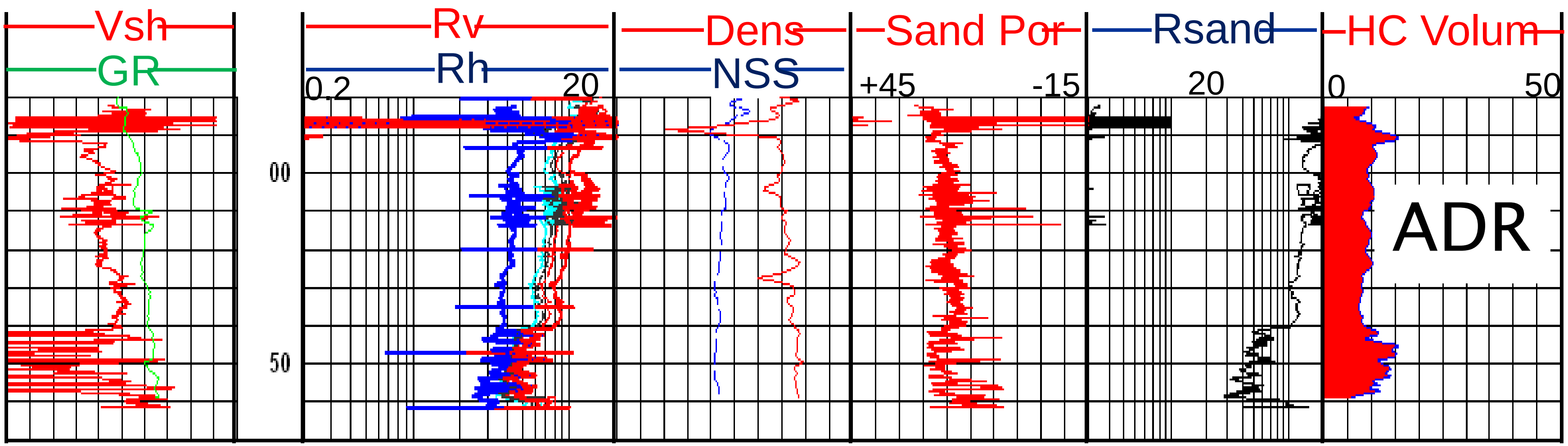
- Halliburton (LASSI)
- Paradigm Geolog
- Powerlog (Petcom)

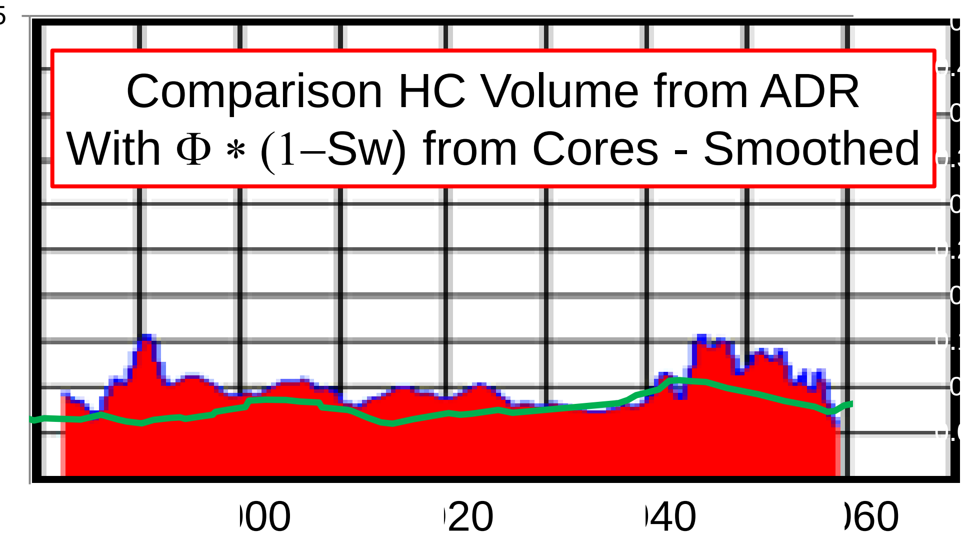
Comparison of Computed Results in TVD
Assuming Rshale (horiz) =2.2 Ohm-m
Shale Anisotropy Ratio = 2.5
ADR vs. EWR

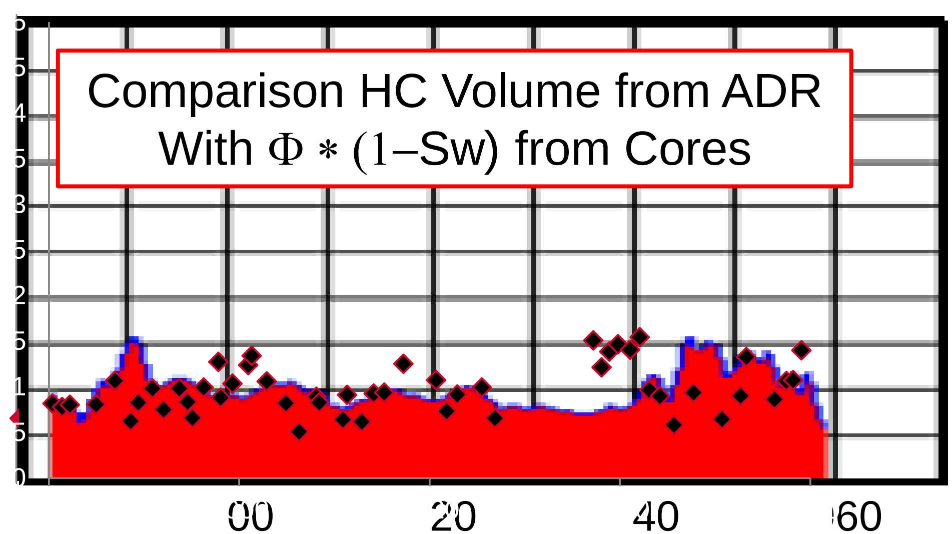


Note: Because Rh(EWR) is low compared to Rshale, Vshale is close to 1.

Comparison of Computed Results in TVD
Assuming Rshale (horiz) =2.2 Ohm-m
Shale Anisotropy Ratio = 2.5
ADR vs. Core







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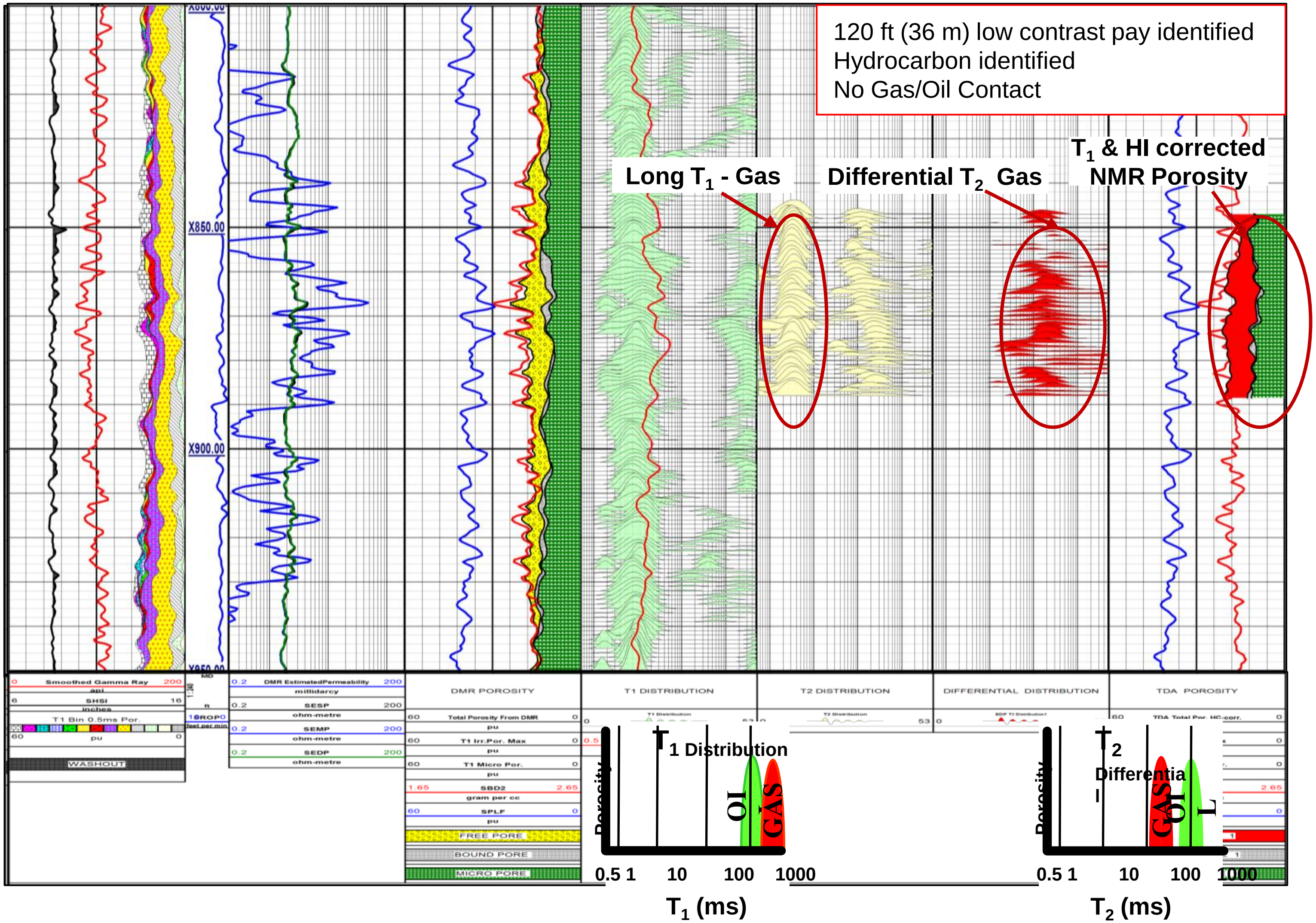
DMR Porosity/T_1 Distribution with TDA Porosity/Differential Distribution

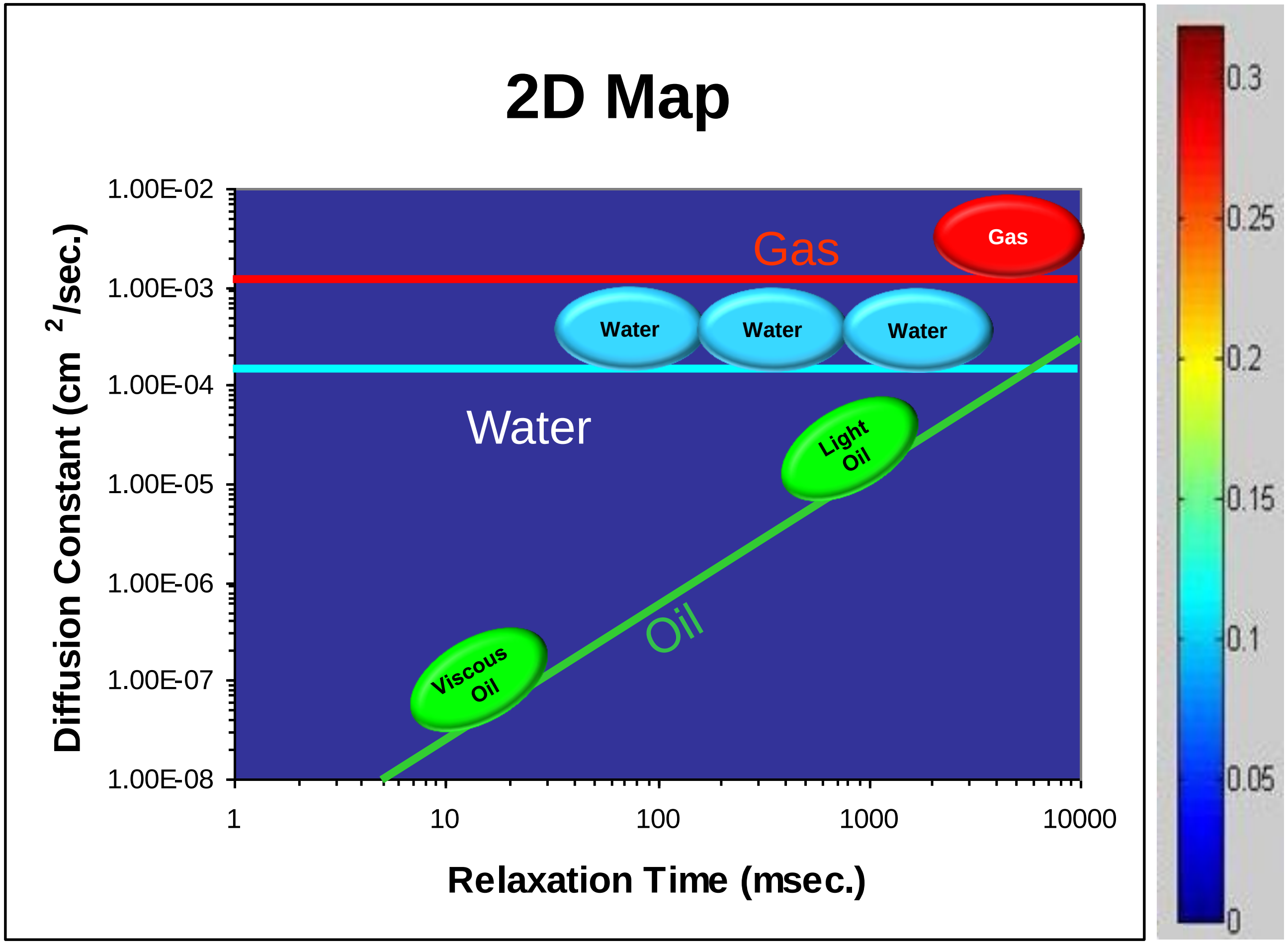
Conventional Data & T_1 Field Log



2DFC-T_2D
(Two Dimensional Fluid Characterization - T_2D)

This process assumes formation is water wet and the gas exhibits bulk properties with no surface relaxation effect

Water
Viscous Oil
Light Oil
Gas

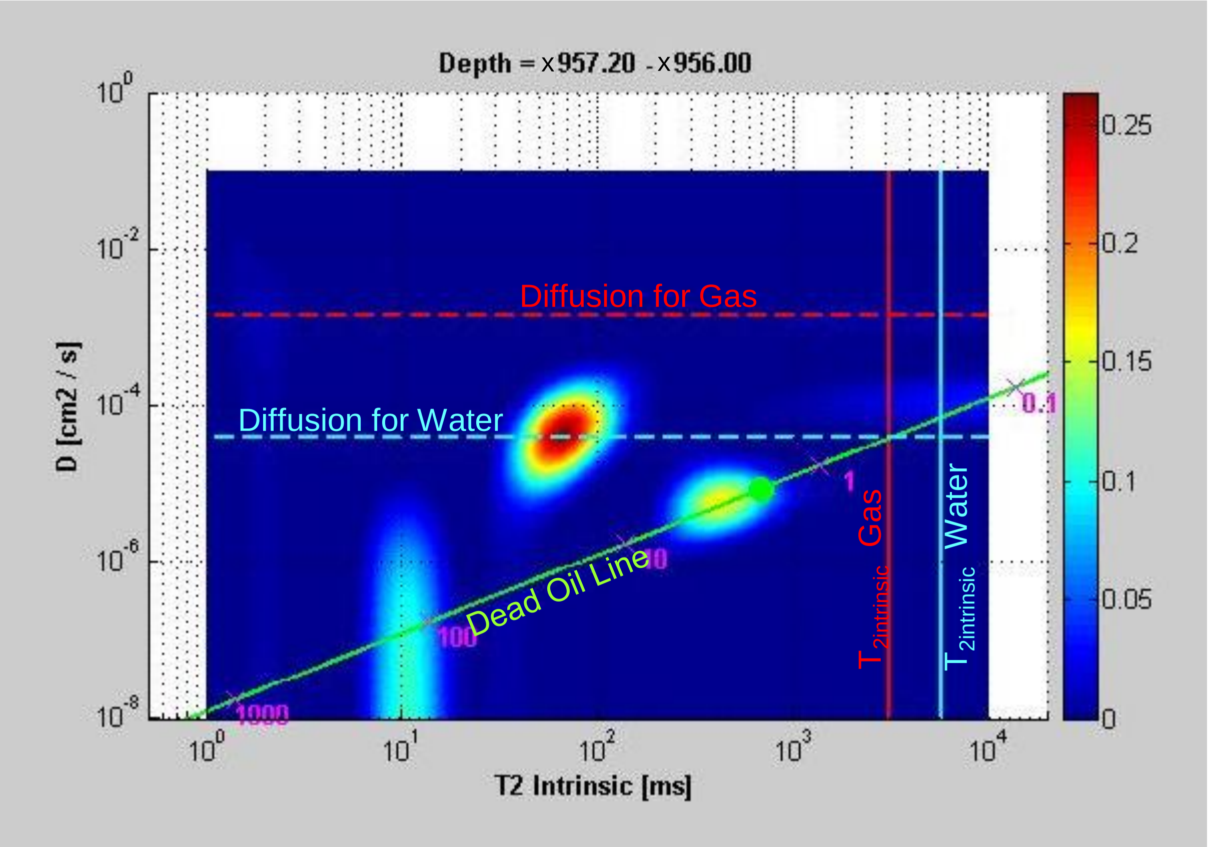


The position of this line is primarily a function of temperature.

2DFC-T_2D
(Two Dimensional Fluid Characterization - T_2D)

Near Wellbore:

- Fluid ID and Volumes
- Viscosity estimation
- Combines all T_1 & T_2 methodologies
- Identification of effects



Water & 6 cp Oil

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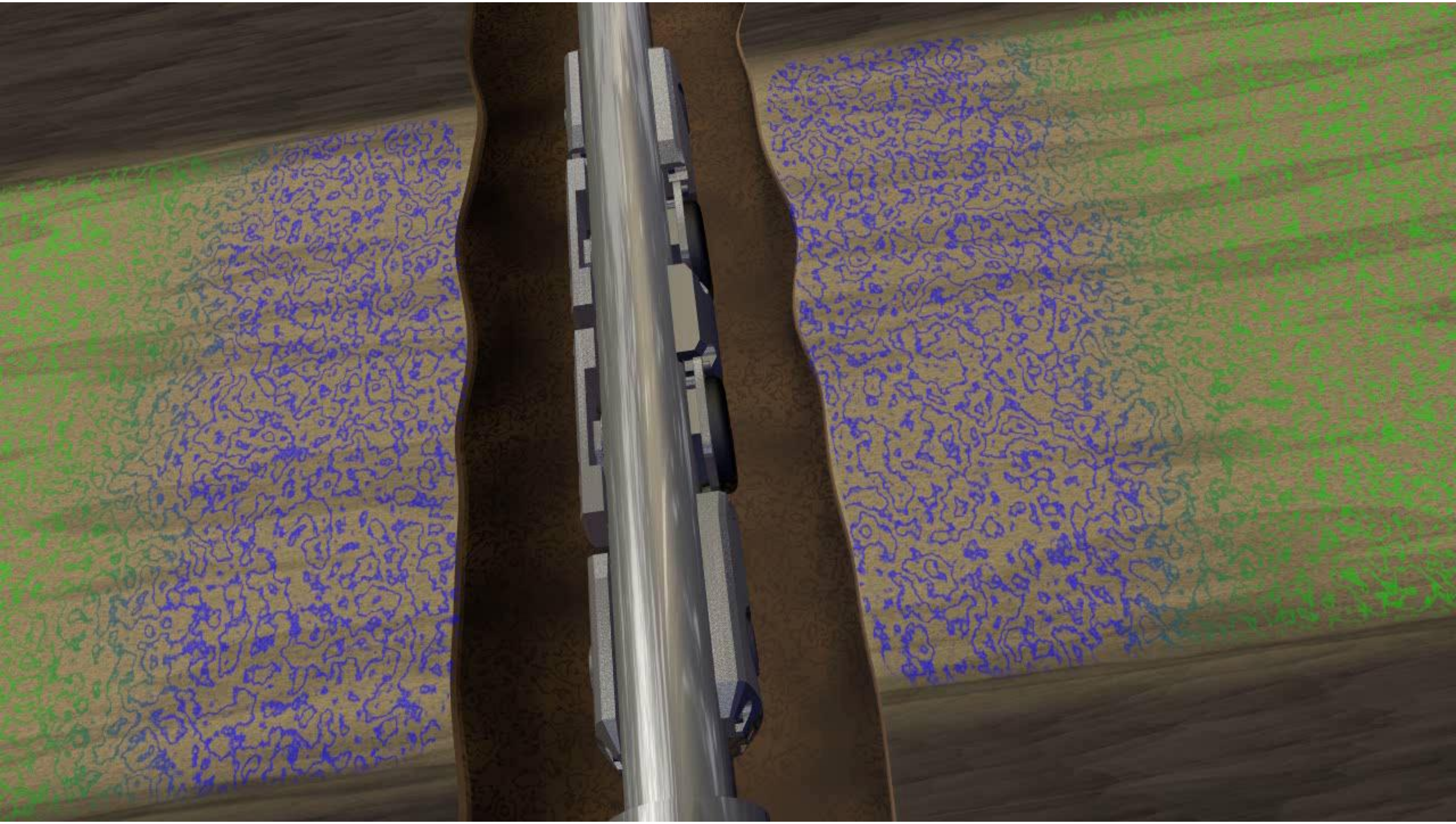
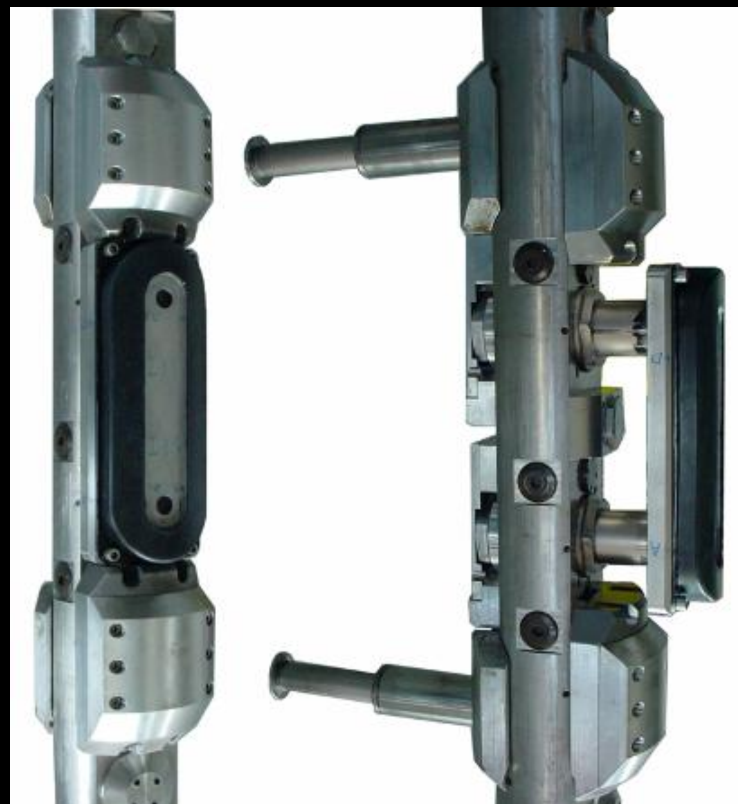
Fluid Sampling For Laminated Reservoirs



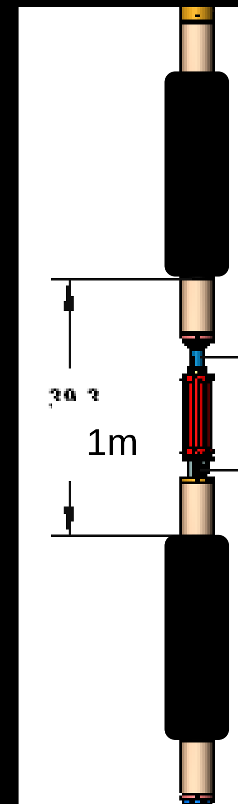
Wireline Tester Intake Configurations

Probes 0.5”

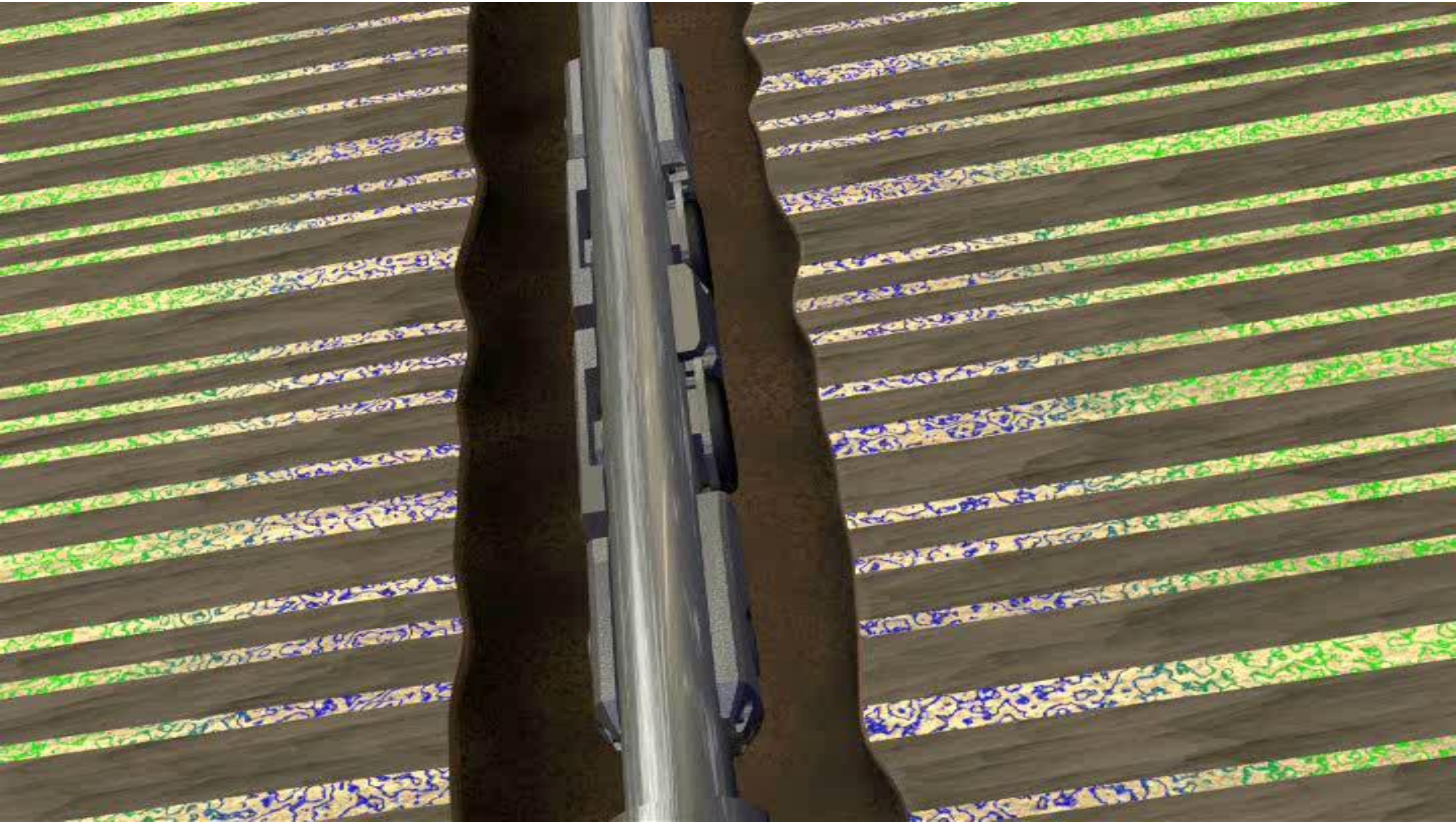
Oval Pad 10”



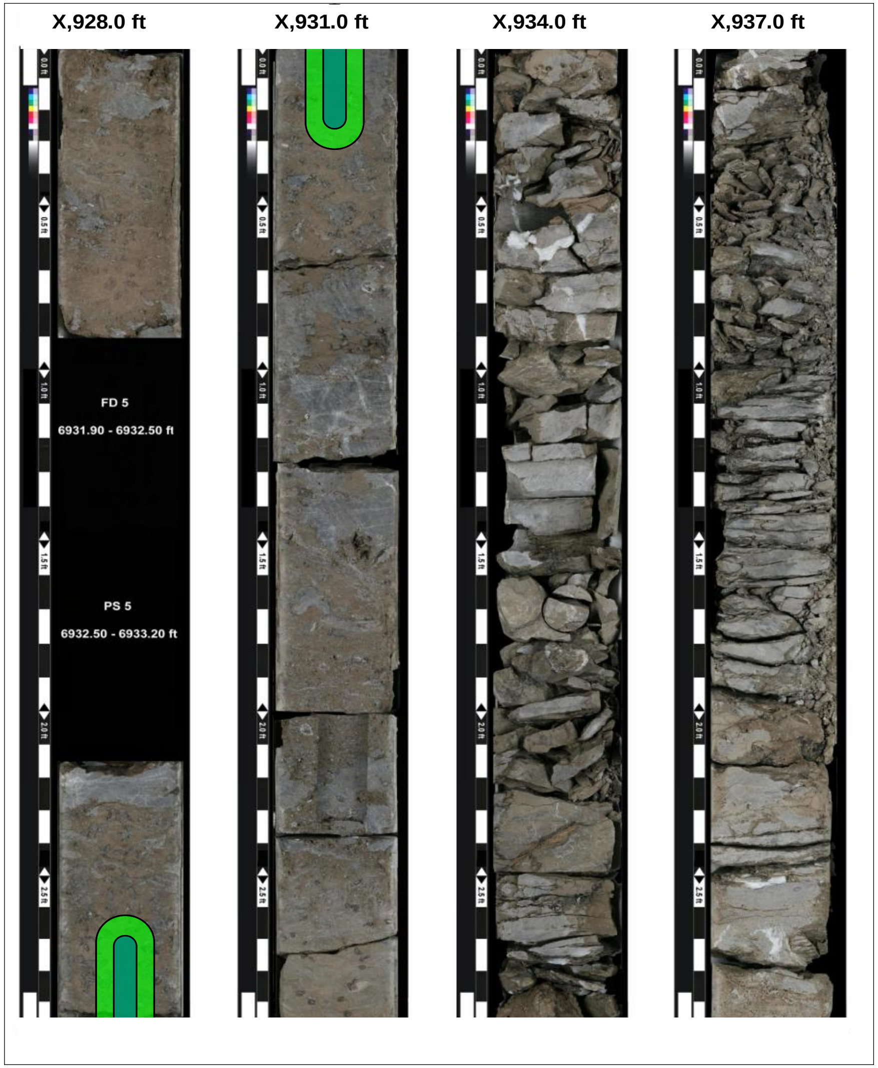
Straddle Packer 40”

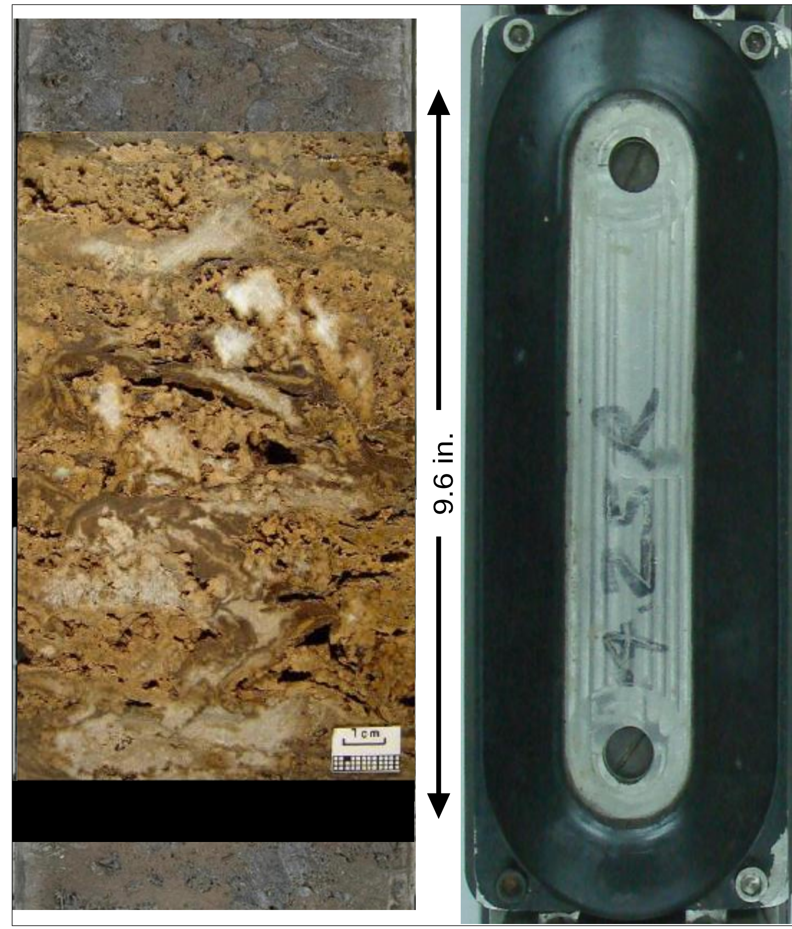


Oval Pad & Straddle PackerTesting & Sampling

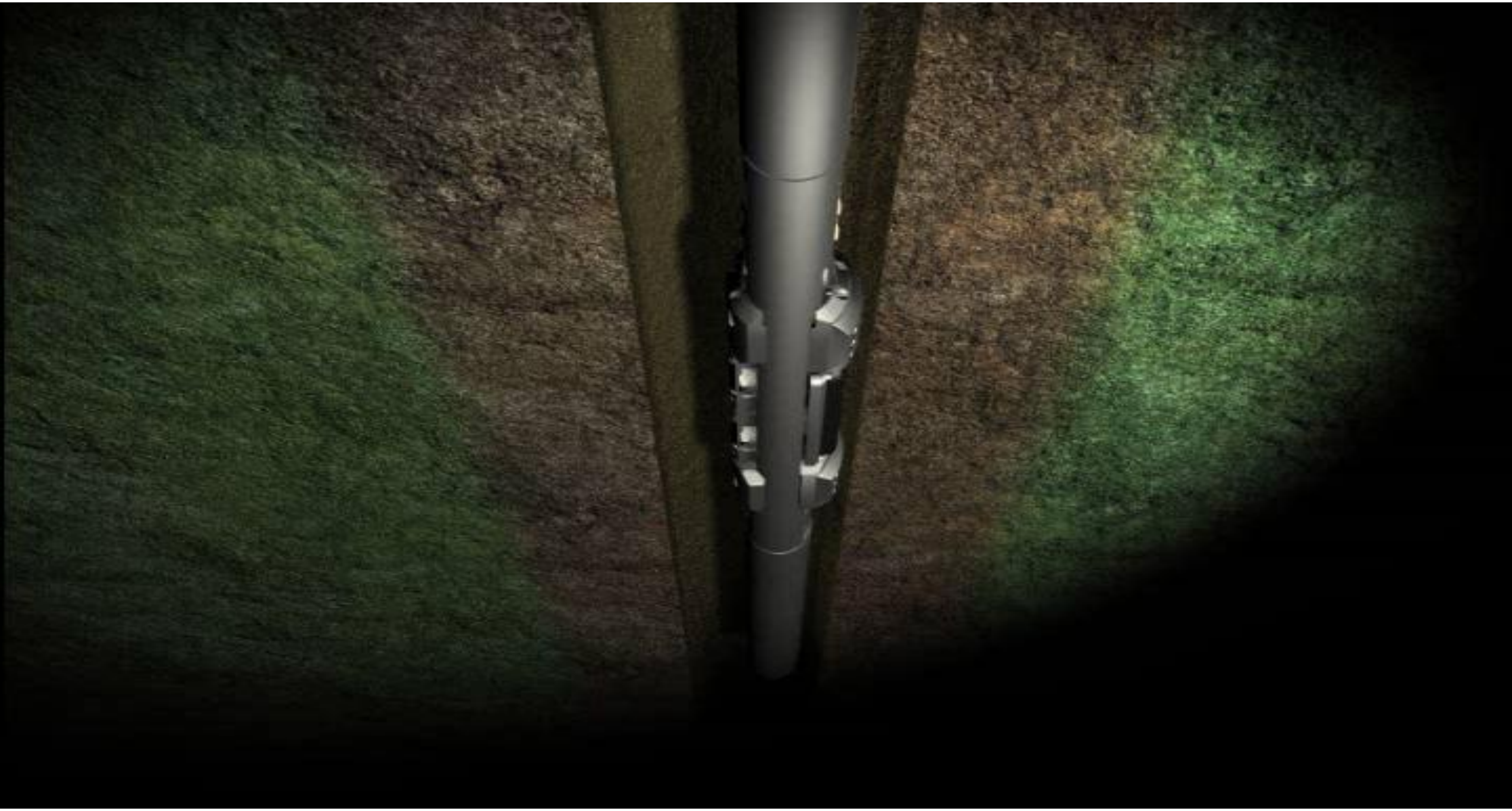


Actual Core - Carbonate Heterogeneity





Focused Oval Pad Sampling

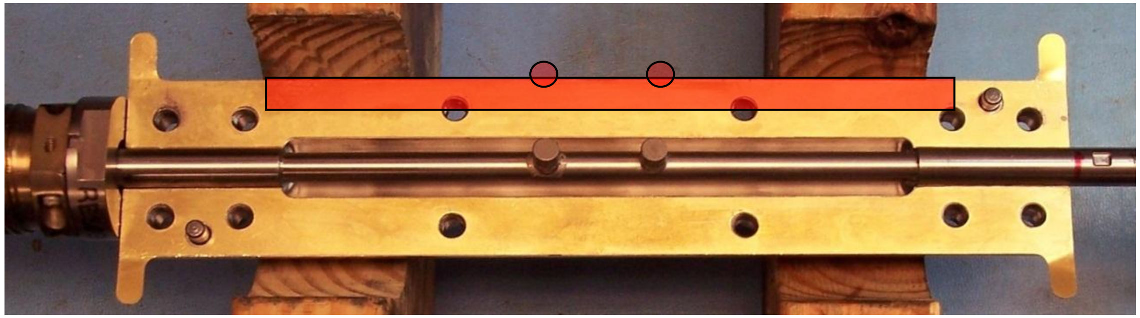


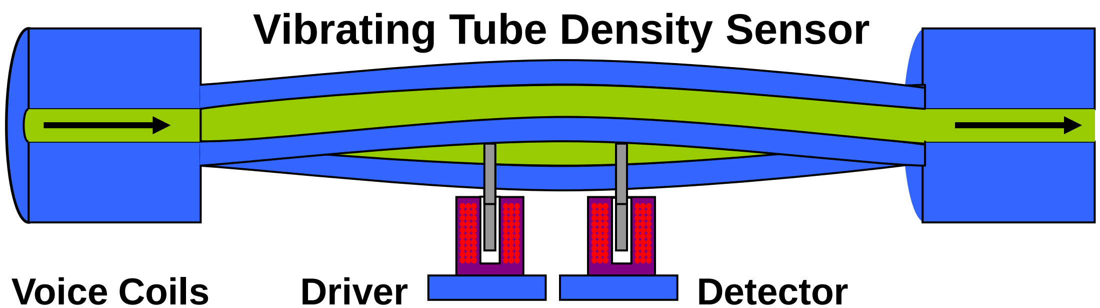
LWD – Fluid ID and Sampling

- Real-time measurements
  - Formation fluid pressure
  - Temperature
  - Resistivity
  - Density
  - Bubble point measurements
- Applications
  - High angle wells
  - Reduced pump out time
  - Data in hours not days
  - Sticky and unstable hole conditions


HALLIBURTON
Sperry Drilling
GeoTap® IDS Sensor

Vibrating Tube Fluid Density Sensor

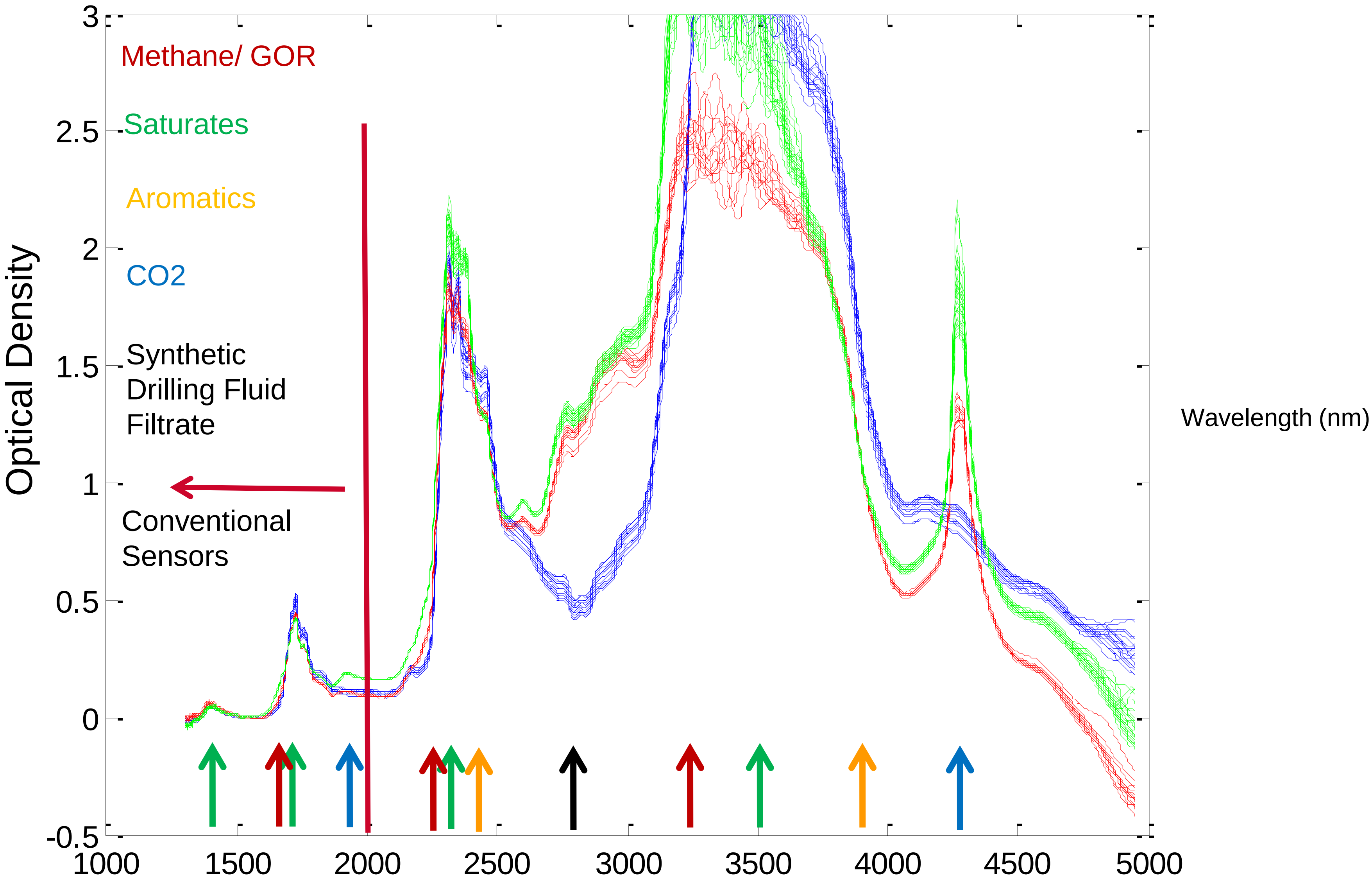




- **Principle of operation:**
  - Vibrating flow tube as sensing element
  - Fundamental resonance frequency is function of fluid density

Accuracy **±0.01 g/cm^3**   High sensitivity **±0.003 g/cm^3**

Advanced Optical Fluid Analyser



Evaluation of Laminated Reservoirs

- Image Guided Deconvolution
- Electrical Anisotropy
- A [illegible] nt [illegible] ethod Wireline
- A [illegible] y Measurement Meth [illegible]
- From Electrical A [illegible] to S [illegible]
- M [illegible] or Fluid Identification
- F [illegible] d Sampling

Terima Kasih

Thank You